JPRS 76414

12 September 1980

USSR Report

MATERIALS SCIENCE AND METALLURGY

No. 70

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CONTENTS

UDC 669.017

CONCERNING THE ROLE OF THE INTERVAL BETWEEN HARDENING AND AGING OF AV AND ADZZ ALLOYS

Ordzhonikidze IVUZ, TSVETNAYA METALLURGIYA in Russian No 2, 1980 pp 105-108 manuscript received 5 Jul 78

BOCHVAR, O. S., POKHODAYEV, K. S., EKHINA, Ye. V., BAZURINA, Ye. Ya. and KUNYAVSKAYA, T. M., Moscow Aviation Technology Institute

[Abstract] The results are given of a study of the kinetics of the aging of AV and ADZZ extruded alloys as a function of the aging temperature and the length of the interval between the operations of hardening and aging, as well as of the influence of this interval on the sensitivity of these alloys to subsequent step-by-step heating. AV alloy has the following composition in percentage by weight: 0.71 Mg, 0.87 Si, 0.29 Mn, 0.2 Fe, 0.33 Cu, 0.03 Ti and H_2 in $cm^3/100$ g, 0.21; and ADZZ alloy: 0.23 Cr, 0.92 Mg, 0.49 Si, 0.3 Fe, 0.31 Cu, 0.03 Ti and H_2 in $cm^3/100$ g, 0.23. The samples used for study were lengthwise specimens cut out of extruded hollow shapes produced from bars of AV and ADZZ alloys measuring 435 mm in diameter. Specimens hardened from 420° C in water and held at the hardening temperature for 45 min were aged. The length of time between the hardening and aging operations determined the nature of the change in the mechanical properties of alloys over time at different temperatures. For AV this interval has an influence on aging kinetics, the time required for reaching maximum values of tensile strength and yield stress and also the level of values of properties. Increasing the aging temperature from 150 to 190° C raises the tensile strength and yield stress with both a 30 min interval at room temperature after hardening and after a seven 24-hr-period interval. An interval of seven 24-hr periods has a favorable influence on the properties of the alloy with both aging temperatures with 15 to 25 hours of aging. For ADZZ alloy the kinetics of aging depend simultaneously on the interval between hardening and aging and the aging temperature. Curves are presented, illustrating the change in the mechanical properties of both alloys when aged at 150 and 190° C the length of the

interval has a greater influence on the yield stress and percentage elongation. An aging temperature of 190° C alters the aging kinetics of both alloys. Curves are presented, showing the change in specific volume of both alloys as the result of aging at 150 and 200° C and the change in their resistivity as the result of aging at 150 and 190° C. Volume changes are considerably less in alloy ADZZ than in alloy AV and depend to a lesser degree on the aging temperature and time. The interval between hardening and aging exerts a considerable influence on the sensitivity of the aged alloys to subsequent step-by-step heating over the range of 140 to 180° C when heated for 1 to 3 hours. The sensitivity of both alloys to the interval between hardening and aging is preserved even after step-by-step heating when these alloys have been hardened and aged at 160° C for 10 hours. Increasing the interval between the two operations to seven 24-hr periods results in a considerable increase in the yield stress and a reduction of percentage elongation for both alloys. A table of comparative data on mechanical properties after step-by-step heating is given for both alloys. Figures 3; references 2: both Russian. [162-8831]

UDC 536.421.1:629.198.3

PRODUCING ALUMINUM-BISMUTH AND ALUMINUM-MAGNESIUM PSEUDOALLOYS UNDER CONDITIONS OF REDUCED GRAVITATION

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 252, No 6, 1980 pp 1387-1389 manuscript received 11 Feb 80

SAVITSKIY, Ye. M., corresponding member of the USSR Academy of Sciences, BUROV, I. V., PIROGOVA, S. V. and SAVEL'YEV, Yu. A., Institute of Metallurgy imeni A. A. Baykov, USSR Academy of Sciences, Moscow

[Abstract] Pseudoalloys in immiscible aluminum-bismuth and aluminum-magnesium systems produced by application of a magnetic field to the molten metal under terrestrial conditions are compared with analogous alloys made under conditions of reduced gravity on board the Salyut-6 satellite. Specimens of aluminum +70 wt.% bismuth were melted in vacuum at 700° C. Then they were recrystalized by uniform heating from room temperature to 800° C over a period of 1 hour, held at this temperature for 18 hours and cooled in the furnace at a rate of 100° C/hour. Microstructural comparison of the terrestrial and space specimens shows a clear interface between the aluminum and bismuth in the terrestrial specimens and considerable intermixing in the specimens recrystallized on the Salyut 6 satellite. X-ray and electron microscope analysis shows that neither component dissolves in the other, i.e., the mixing is only by mutual interpenetration. It is suggested that in future experiments the melt should be agitated and a higher temperature should be used for total intermixing. The aluminum-magnesium pseudoalloys (52 wt.% magnesium)

were grown under terrestrial conditions by the Bridgman technique as single crystals. In outer space the crystal was remelted and held at a temperature of 600° C for 2 hours. The resultant polycrystal specimen showed no change in chemical composition or microhardness of the gamma phase, but it was observed that the gaseous CO and CO_2 contained in the graphite crucible are trapped in the molten metal. Since Archimedes forces prevent this effect under terrestrial conditions, the absence of such forces under the conditions of reduced gravity should enable production of pseudo-alloys based on two or more immiscible components in the solid and liquid states, as well as porous materials of gas-metal systems. Under weightless conditions there is no limit on the number of components in the alloy, or on their specific weight or type of electrical conductivity. Figures 3; references 4: all Russian.
[161-6610]

UDC 621.793.8:669.718.58

DIFFUSION ZINC PLATING OF THE D16T ALLOY

Ordzhonikidze IVUZ. TSVETNAYA METALLURGIYA in Russian No 3, May-Jun 80 pp 126-127 manuscript received 12 Jun 79

DUBININ, G. N. and KUSHNARENKO, A. P., Chair of Aircraft Materials Science, Moscow Institute of Civil Aviation Engineers

[Abstract] A study was made to determine the role of the diffusion layer during zinc plating of the D16T aluminum alloy. Specimens were plated by the liquid-phase process at temperatures ranging from 450 to 550° C. Metallographic analysis revealed that two different kinds of diffusion layers can form. During treatment for less than 15 min at 450-500° C a 60-80-μm layer of α-phase solid solution with Mg_2Zn_{11} inclusions builds up. During treatment for more than 30 min at 500-550° C a bizonal layer consisting of a 10-30 μm thick pinnate heterostructure outside and a 180-200 μm thick α-phase solid solution inside builds up. A significant redistribution of elements within the diffusion layer thus occurs as treatment near 500° C is prolonged. Results of both microhardness tests and x-ray spectral microanalysis indicated an exponential temperature dependence of the layer thickness and a parabolic temperature dependence of the layer buildup rate. The study confirms that zinc plating by the diffusion process with a cycle stress not exceeding 225 MN/m^2, while increasing the corrosion resistance of the D16T aluminum alloy five- to sevenfold, raises its endurance limit and lengthens its life in typical 30 Hz vibration tests. This is attributable to changes in the surface energy and fine structure which inhibit cracking. Figures 1; references 1 Russian.
[170-2415]

UDC 629.735.33.018.4-97:620.178.3

RELAXATION OF RESIDUAL STRESSES IN DURALUMIN AT NORMAL AND ELEVATED TEMPERATURES

Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 80 pp 50-52 manuscript received 21 Jun 79

VISHNYAKOV, N. A., GRINGAUZ, G. D. and RUDZEY, G. F., Novosibirsk

[Abstract] In a continuation of experimental studies pertaining to residual stresses in duralumin specimens with stress concentrating holes, tests were performed on relaxation of these stresses by aging at 150° C for 100 min, 7 days, and 30 days respectively. Aging at room temperature (20° C) for 7 days was also included. All specimens had been loaded in tension to 70% ultimate strength before aging and were cycled with a load amplitude equal to 50% ultimate strength after aging. Microhardness measurements and life data indicate that at elevated temperature the microhardness increases with aging time up to 7 days and then decreases with longer aging time. The life becomes, correspondingly, first shorter and then longer. These conclusions are consistent with available data on phase transformations in aluminum-copper alloys. Figures 3; references 4: 2 Russian, 2 Eestern.
[171-2415]

UDC 539.4

DEFORMATION KINETICS TEST FOR THERMAL FATIGUE STRENGTH

Kiev PROBLEMY PROCHNOSTI in Russian No 2, 1980 pp 3-11 manuscript received 24 Feb 78

KOTOV, P. I., GUSENKOV, A. P., VASHUNIN, A. I., GENKIN, G. I., KHOROSHILOV, V. N. and FEDOROVA, Ye. T., Moscow Aviation Technology Institute and State Scientific Research Institute of Machine Sciences imeni Academician A. A. Blagonravov

[Abstract] For the purpose of estimating sustained low-cycle strength under isothermal conditions data are used on the accumulation of damage either in terms of unit durability or unit deformation. In the first case damage is summed nonlinearly, and in the second linearly. In thermal fatigue tests of a group of heat-resistant alloys it has been found that there is a considerably nonlinear interrelationship between fatigue and sustained static damage when these types of damage are estimated in terms of unit durability. It has also been domonstrated that a deformation interpretation of failure is possible by taking into account the specifics of the elastoplastic deformation process. Here data are given on the EP693VD heat-resistant alloy derived from thermal fatigue tests conducted according to a special program in which the proportion of fatigue and sustained static damage was monitored. On the basis of these data, rules are established for the linear summation of these types of damage on the basis of a deformation kinetics test for low-cycle failure under conditions of elevated and high temperatures in the isothermal testing of materials. The test describes the conditions for reaching the limiting state for failure of the quasi-static and fatigue types for mild, rigorous and medium loading embracing the features of non-steady-state cyclic deformation characteristic of thermal fatigue tests. The assumption is made that failure in thermal fatigue loading and under conditions of isothermal sustained low-cycle deformation is caused by the accumulation and interrelationship of fatigue and quasi-static, i.e., sustained static, damage. According to the deformation kinetics test for sustained low-cycle failure employed, the maximum number of loading cycles at the stage of crack formation is determined by the linear summation of quasi-static and fatigue damage while taking into account the change from cycle to cycle in linearly accumulated and cyclic deformation, as well as the change over time in

the sustained plasticity of the material. The basic equation for this test is presented, along with the form of this equation used when employing a dependence of the Manson-Coffin type for an analytical description of the low-cycle fatigue curve. Fatigue curves and data on the material's available plasticity are employed for determining the proportion of fatigue and sustained static damage, respectively. A description is given of a combined testing program carried out to take into account the specifics of the elastoplastic deformation process under conditions of thermal fatigue loading and the key tenets of the deformation interpretation of conditions for failure in low-cycle loading. This program consisted of thermal fatigue tests with and without aging, basic isothermal and nonisothermal low-cycle thermal fatigue tests under rigorous conditions for the purpose of obtaining basic data on fatigue characteristics, and corresponding creep tests for the purpose of determining the regular behavior of sustained plasticity. Thermal fatigue tests were conducted on solid cylindrical models 8 mm in diameter and 25 mm long with the automatic recording of cyclic deformation diagrams under nonisothermal heating. The thermal loading cycle was controlled by keeping constant from cycle to cycle the limiting values of the temperature at the middle of the working length of the sample, i.e., 200 to 900° C. Failure was recorded in terms of the instant of formation of a macrocrack. The proportion of fatigue and quasi-static damage was monitored by varying the severity of loading. Failure took place over a wide range of numbers of loading cycles from 60 to 6×10^3. Experiments were conducted with complicated testing units containing servo loading systems and an independent programmed heating system. Tests were also conducted [illegible]lt of the UME-10t type without a servo loading system, whereby it was demonstrated that for EP693VD alloy basic experiments can be conducted under isothermal conditions at the maximum temperature of the thermal cycle and that for this alloy the results are equivalent to those obtained under nonisothermal conditions. The combination of basic data arrived at was used to calculate the fatigue and sustained static damage to the material in the process of thermal fatigue testing. Characteristic is the fact that as the number of cycles increases a transition is made to a mode of failure in which the proportion of fatigue damage prevails with a simultaneous lowering practically to zero of sustained static damage. The deformation interpretation of conditions for failure under sustained cyclic loading confirms the linear law of summation of damage not only under isothermal, but also under nonisothermal conditions in thermal fatigue loading. If an estimate of damage is made in terms of unit durability, under both isothermal and nonisothermal loading a considerable deviation from the linear summation rule is observed. It is demonstrated that for thermal fatigue tests the expression of results in the currently widely used form in which cyclic deformation, either total or irreversible, is plotted against durability is insufficiently correct. Failure to take into account the influence in thermal fatigue testing of quasi-static damage, whose role increases as the durability of samples is reduced, results in the observation of an apparent four- to fivefold reduction is resistance to thermal fatigue

stress, as compared with the material's fatigue curve. It is stressed that the application of the deformation kinetics test discussed here requires further study before it can be generalized for different types of materials and different testing conditions. Figures 8; references 20: all Russian.
[107-8831]

UDC 539.216.2:533.9

STRUCTURE AND PROPERTIES OF COATINGS PRODUCED BY PLASMA BURST SPRAYING

Moscow FIZIKA I KHIMIYA OBRABOTKI MATERIALOV in Russian No 3, 1980
pp 68-72 manuscript received 13 Nov 77

KIRKO, V. I., Novosibirsk

[Abstract] The results are given of an experiment conducted for the purpose of studying some of the properties and structures of coatings produced plasma burst spraying. A plasma-burst compressor made it possible to produce a plasma with an energy of from 40 to 140 kJ and a specific energy of approximately 40 kJ/g with a plasma density of 10^{-2} to 10^{-1} g/cm^3. The plasma was emitted from the compressor at a rate of 10 to 20 km/s. These parameters were varied by changing the volume of the compression chamber or the mass of the working substance filling the chamber. This substance was either C_8H_8, $(C_6H_{10}O_5)_n$ or air. An explosive charge forced the plasma from the compressor into the space of a metal container at the bottom of which lay the powder to be sprayed. This container served as the substrate and while its space was being filled with plasma the surface of its wall reached the melting point and above. Powder particles accelerated by the heavily turbulent plasma under these conditions are introduced into the surface melt at a rate of approximately 10^4 to 10^5 cm/s. Responsible for this speed of particles measuring 10 microns at distances of approximately 1 cm are the high density of approximately 0.1 g/cm^3 of the plasma and the speed (approximately 10^6 cm/s) of the plasma. After blasting of the compressor, specimens were cut from the walls of the container for the purpose of making microsections. The structure of the coatings was studied by metallographic, x-ray structural and micro-x-ray spectral analysis and the properties of coatings were studied by measuring microhardness by means of an accessory for the "Epitip-2" optical microscope. It was demonstrated that with premelting of the substrate, on the surface of the walls a coating is formed with a complex structure consisting of several layers. In each coating it was possible to distinguish a typical layer characterizing the type of structure formed and usually representing the thickest layer. Data are given on the chemical composition and type of structure of the characteristic layer, metastable phases, and microhardness of the chemical film. The results obtained made it possible to identify characteristic features of plasma burst spraying. This method

differs from other methods of applying coatings primarily in that it makes it possible to premelt the substrate. Coatings with special properties can be formed as the result of the addition of powder particles to the surface melt of the substrate. It is demonstrated that the structure of these coatings depends on the relative physicochemical activity of the materials of the powder and substrate as well as on the hardening rate of the surface melt. Four main types of structures are formed, three of which are typical only of plasma burst spraying. These consist of a film made up of the powder material and the following: I--a diffusion layer and the substrate; II--a finely divided mixture, an $\alpha \rightarrow \gamma \rightarrow \alpha'$ zone and the substrate; III--a homogeneous solution, a diffusion layer, an $\alpha \rightarrow \gamma \rightarrow \alpha'$ zone and the substrate; and IV--a chemical compound, an $\alpha \rightarrow \gamma \rightarrow \alpha'$ zone and the substrate. Figures 3; references 8: all Russian. [167-8813]

UDC 539.6:678.01

EFFECT OF CYCLIC BENDING ON THE PROPERTIES OF POLYMER COATINGS

Riga MEKHANIKA KOMPOZITNYKH MATERIALOV in Russian No 2, 1980 pp 353-355
manuscript received 2 Mar 79

VORONIN, I. V. and KONDRASHOV, E. K., Moscow, All-Union Scientific Research Institute of Aviation Materials

[Abstract] Polymer coatings used to protect structural materials as well as for decorative purposes often perform under cyclic loading conditions. Hence the effect of cyclic bending on the performance of such coatings was investigated, with strength and proneness to cracking selected as criteria. Specimens of D16 sheet alloy with and without cladding were anodized in sulfuric acid and spray-painted with EP-076 primer. The thickness of the primer coating was 40-50 μm. The specimens were then subjected to symmetrical cyclic bending at 2 and 16 kg/mm^2 at frequencies of 50-60 Hz at 20° C, in the "as is" state as well as following immersion in a 3% NaCl solution for 360 hr and following thermal aging at 100° C for 500 hr. Although the specimens did not crack they underwent a cohesive type of fracture, i.e., their cohesive strength decreased markedly. Immersion in a corrosive medium and thermal aging had an adverse effect on the bending resistance of the coatings. An equation describing the relation of the strength of the coatings to the number of bending cycles and the maximum deformation in a cycle is proposed. Figures 2.
[151-1386]

UDC 62-419.4:669.721'781

SELECTION OF ALLOYING ELEMENTS FOR COMPOSITE MATERIALS OF THE Mg-B SYSTEM

Moscow METALLOVEDENIYE I TERMICHESKAYA OBRABOTKA METALLOV in Russian
No 5, 1980 pp 50-52

FORTNOY, K. I., STROGANOV, G. B., BOGDANOV, V. I., MIKHAYLOV, A. V. and FUKS, D. L.

[Abstract] Composites with a magnesium matrix reinforced by boron fibers display a particularly high specific tenacity. Their development is just beginning. This requires further research into the alloying of the Mg matrix to improve compatibility between fibers and the matrix. Three models of solid solutions of boron atoms in the Mg matrix were analyzed, using Si, Al, Sc, Mn, Zn, and Cd as alloying elements in concentrations of 0.5 at.% (except for Si = 0.05 at.%). Comparison of the parameters of interaction of boron with alloying element in the Mg matrix shows that for boron alloyed with silicon or aluminum these parameters are positive; for B alloyed with Mn, Zn, and Cd, these parameters become negative. This means that treatment with Si and Al will reduce the solubility of fibers, whereas Mn, Zn, and Cd should intensify the processes of fiber dissolution and enhance the amount of the intermediate phase forming. A correlation is found between the valence of the alloying element and its effect on the solubility of fiber in matrix: the higher the valence of the alloying element, the lower the solubility. This is because an increase in valence results in a stronger Coulomb repulsion between boron ions and alloying elements. This offers a way of predicting matrix compositions in composite materials. Figures 1; references 6: 4 Russian, 2 Western.
[152-1386]

UDC 539.216.539.4

INFLUENCE OF PLASTIC DEFORMATION ON INTERNAL FRICTION OF A NIOBIUM-TITANIUM ALLOY - COPPER COMPOSITE MATERIAL

Moscow FIZIKA I KHIMIYA OBRABOTKI MATERIALOV in Russian No 3, 1980 pp 140-144 manuscript received 11 Sep 78

SOMOV, A. I., TOMSKAYA, L. A. and SHAPOVAL, B. I., Khar'kov

[Abstract] The results are given of a study by the method of amplitude-dependent internal friction of features of the stressed-strained state in drawing a wire made of the composite material NT-50 - copper with a degree of deformation of up to 99.99 percent. Deformation to high degrees is accompanied by the intense accumulation of imperfections in the alloy's lattice, ultimately resulting in breaking of a thread; therefore data are obtained on the nature of the process of the accumulation of imperfections. This composite, when properly fabricated, exhibits an almost ideal metallic bond between components, resulting in a minimum of external friction losses. Measurements of internal friction were made in samples measuring in diameter from dozens of millimeters to dozens of microns. The sample of wire was fastened to a frame at both ends by means of clamps, and a crossarm fastened at the center of the sample was used to excite torsional vibrations. By means of this method it was possible to limit considerably the undesirable influence of instability of the sample in the measuring process. Disregarding the weight of the crossarm, longitudinal tension was absent. The raw materials for the samples consisted of sponge titanium, electrolytic niobium, and pure copper. Both single-strand and multistrand samples were made, the latter having more than 40 strands. The samples were annealed in vacuum under a pressure of not higher than $5 \cdot 10^{-6}$ mm Hg. Data are presented on measurements of the amplitude dependence of internal friction of a single-strand composite wire which had been pretreated by drawing at room temperature with a degree of deformation of 99.9 percent without subsequent annealing, for a wire made of alloy NT-50 and for a wire made of pure copper, all having undergone the same treatment. For the first sample the presence of two maxima at amplitudes of $\varepsilon = 4 \cdot 10^{-5}$ and $9 \cdot 10^{-5}$ was observed. A distinctly pronounced amplitude dependence was observed for the sample with a composite structure, whereas for the NT-50 alloy and pure copper practically no such dependence was seen. The level of internal friction of the composite was considerably greater than that of its components even at the initial amplitudes of vibrations. Also presented are curves illustrating the influence of annealing at different temperatures on the amplitude dependence of internal friction of the composite after it was deformed by drawing. Annealing at a temperature as low at 200° C was sufficient for practically total elimination of the differences between the amplitude dependence of internal friction of the composite and its components. Annealing results in a reduction of internal friction. A suggested mechanism for this reduction is discussed. The level of internal

friction measured at a specific temperature and amplitude of vibrations serves as an indirect characterization of the number of imperfections in the lattice. The dependence of the level of internal friction on the degree of deformation to a certain degree reflects the process of the accumulation of defects. For the deformation range of 97 to 99.99 percent, the process of the accumulation of lattice defects for this composite material obeys a practically linear law. Figures 4; references 9: 7 Russian, 2 Western.
[167-8831]

UDC 541.67

EFFECT OF DIELECTRIC GAPS ON THE CONDUCTIVITY OF RESISTIVE COMPOSITES

Kiev POROSHKOVAYA METALLURGIYA in Russian No 4, Apr 80 pp 85-89 manuscript received 1 Aug 79

BONDARENKO, E. A., PYATKIN, A. A., GREBENKINA, V. G. and GARAYMOVICH, O. A., Institute of Problems of Material Science, UkSSR Academy of Sciences

[Abstract] The contact resistance of gaps formed by quasi-spherically undeformed particles and formed by deformed particles and in composites containing a conducting binder was studied and the mathematical relationships for all three dielectric systems described. The possibility is shown of creating thermally stable composites by means of the effect of mutual compensation of temperature increments of both the conducting particles and gap resistances. The necessary relationships have been theoretically established between the coefficients of thermal expansion of the conductor and binder which provide the creation of thermally compensated systems. References 1 Russian.
[133-6368]

UDC 621.762

ACTIVATED GRAPHITIZATION OF CARBON FIBERS IN A COMPOSITE WITH A NICKEL MATRIX

Kiev POROSHKOVAYA METALLURGIYA in Russian No 4, Apr 80 pp 57-62 manuscript received after reworking 30 Oct 79

OVCHARENKO, V. Ye., TUROVETS, L. A., DUDAREV, Ye. F., ZABOLOTSKIY, A. A., TREGUBOV, V. F., and SALIBEKOV, S. Ye., Siberian Physico-Technical Institute

[Abstract] The kinetics of activation graphitization were investigated using VMN-4 carbon fibers produced from a copolymer of polyacrylonitrile coated chemically with nickel to produce a solid nickel coating 0.8--1 micron

thick. Then the fibers were additionally coated with nickel electrolytically and soaked at 800, 950, 1000, 1050 and 1100° C in a vacuum of $5 \cdot 10^{-5}$ mm Hg. After dissolving the nickel coating, the fibers were examined. In this method graphitization of the fibers starts at the instant of nickel diffusion into the fibers where the graphitization development is accompanied by an increase in the nickel content up to several hundredths of a mass percent in the completely graphitized fibers. The high degree of disperaity of the internal structure of the fibers plays a decisive role in the nucleation and development of the graphitization process. A diagram is proposed for the nickel activated graphitization of carbon fibers according to which the graphite phase is formed by means of packing structural complexes representing defect-free sections of basal planes (002) of the graphite structure. Figures 7; references 16: 3 Russian, 13 Western. [133-6368]

UDC 621.746.6

ON THE PROCESS OF HEAT TRANSFER BETWEEN COMPONENTS IN A CASTING OF A FIBROUS COMPOSITE MATERIAL

Minsk IZVESTIYA AKADEMII NAUK BELORUSSKOY SSR, SERIYA FIZIKO-TEKHNICHESKIKH NAUK in Russian No 4, 1979 p 119 manuscript received 19 Dec 78

PROKOPOV, I. P., Physico-Technical Institute, Belorussian SSR Academy of Sciences

[Abstract] The problem of heat transfer between continuous cylindrical reinforcing fibers and a liquid metal matrix is solved by an approximate method for various modes of casting such a composite material. Design formulas are derived for calculating the fiber temperature and the melt temperature as functions of the length of the thermal interaction time and of the thermophysical properties of the composite, and also of the heat transfer rate at its surface of contact with the ambient medium. Relations are derived for calculating the depth and the duration of heat flow in reinforcing fibers at a constant or a variable melt temperature. The developed method makes it possible to control the process of casting composite materials and to correctly optimize the process conditions. The manuscript has been deposited at the All-Union Institute of Scientific and Technical Information, No 1122-79 Dep. References 17. [153-2415]

UDC 539.2:677.5

TEMPERATURE-INDUCED DEFORMATIONS OF CARBON FIBERS

Riga MEKHANIKA KOMPOZITNYKH MATERIALOV in Russian No 2, 1980 pp 350-353
manuscript received 20 Jul 79

PEREPELKIN, K. Ye. and GELLER, A. B., Leningrad Affiliate With Experimental Plant of the All-Union Scientific Research and Project Design Institute of Artificial Fibers

[Abstract] The behavior of carbon fibers with different degrees of structural ordering (graphitization) in the presence of varying temperatures was experimentally investigated. The fibers were heated from -70° C to 20° C at the rate of 2° C per minute or heated and cooled cyclically within the 20-250° C range while being measured on a specially designed vertical optical dilatometer. Within the range of from -70 to 180° C the temperature-induced deformation (TID) of the carbon fiber with the more ordered structure (specimen I, interplanar distance 0.343 nm) is negative and practically linear. At >180° C the strain rate decreases and at ~250° C the change in deformation with temperature is zero. The behavior of carbon fiber with the less ordered structure (specimen II, interplanar distance 0.360 nm) follows the same pattern, but not as distinctly. It is noteworthy that with an increase in temperature the length of carbon fibers decreases, i.e., negative linear expansion (linear compression) occurs. This can be explained by the theory of the anomalous law of variance of vibrations in strongly anisotropic media. Figures 3; references 17: 12 Russian, 5 Western.
[151-1386]

UDC 539.4:678-067.5:620.1

FRACTURE AND WEAR OF COMPOSITE MATERIALS ON INTERACTION WITH FLOW OF ABRASIVE PARTICLES

Riga MEKHANIKA KOMPOZITNYKH MATERIALOV in Russian No 2, 1980 pp 235-240
manuscript received 2 Jul 79

KARIMBAYEV, T. D., NOZHNITSKIY, Yu. A., GUNDAROV, V. I., RYSIN, L. S., LYUTSAU, V. G. and TARASOV, I. A., Moscow

[Abstract] Abrasive erosion of a broad variety of composite materials and alloys was experimentally investigated on a test stand. The tests were carried out with the aid of quartz sand particles measuring up to 40 μm in size, with a concentration of about 10^{-3} kg of the particles per cubic meter of the air blast, with the air blast velocity amounting to 200 m/sec at the outlet of the blast nozzle. The tests showed that

reinforced plastics (glass-, carbon-, organo-, and boron-reinforced plastics), carbon-reinforced aluminum, and boron fiber-reinforced materials with an aluminum or magnesium matrix are less resistant to abrasive erosion compared with such metal alloys widely used in machine building as 1Kh17N2, VT8, and D16T. As regards powder, metallurgical coatings (SiC, Si_3N_4, Al_2O_3, etc.), their wear resistance is largely a function of the properties of their binders. The mechanism of the fracture of materials varies, but reinforcing fibers generally undergo brittle fracture. In general, a fiber-reinforced composite exposed to a flow of abrasive particles cannot be regarded as an integral material, since it is more susceptible to erosion at some points than at others. Polymatrix materials or special protective coatings appear to be the most promising means of enhancing the wear resistance of products manufactured from composites. Figures 1; references 29: 26 Russian, 3 Western.
[151-1386]

UDC 624.074.4:678

ON THE OPTIMIZATION OF THE DESIGN OF COMPOSITE-MATERIAL SHELLS UNDER STABILITY AND STRENGTH CONSTRAINTS

Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 80 pp 109-111 manuscript received 24 Jan 79

NARUSBERG, V. L. and UPITIS, Z. T., Institute of Polymer Mechanics, Latvian SSR Academy of Sciences

[Abstract] The problem of optimizing the design of shells is considered in the case of a composite material consisting of a binder and reinforcement fibers. The problem is formulated as one of minimizing the shell mass, according to the economy criterion, with a given volume of reinforcement fibers to satisfy given stability and strength requirements. A solution is found from the tensor-invariant equation of the strength surface, where the tensor components are functions of the fiber lay angle, first generally and then more precisely with interaction between elementary layers of the stack taken into account on the basis of empirical relations between tensor components and fiber lay angle. As a practical example the optimum design of a cylindrical multilayer glass-plastic shell (ETsT-1 or EFB-3 binder and VMPS 607 fibers) is considered with its state of stress assumed to be a zero-moment plane and subcritical one. A numerical solution has been obtained by the method involving projection of the Rosen gradient. Figures 1; references 3: all Russian.
[171-2415]

UDC 629.7:678.5

PURE SHEAR FRACTURE OF A PRISMATIC BODY MADE OF A REINFORCED PLASTIC WITH AN INTERNAL CIRCULAR CRACK: ENERGY AND FORCE APPROACHES

Riga MEKHANIKA KOMPOZITNYKH MATERIALOV in Russian No 2, 1980 pp 360-362
manuscript received 25 Jun 79

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[Abstract] The critical stress at which a prismatic body of a transversally isotropic material (a reinforced plastic) undergoes fracture or an avalanche-like crack propagation is determined for the case of a body containing an internal flat circular crack that is subjected to pure shear. It is assumed that the plane of the shear lies in the plane of the isotropy. The problem is investigated by procedures of the elasticity theory using Griffith's energy method. It was established that the limiting shear stress of fibrous composites with internal round cracks is a function of the anisotropy of the elasticity properties, crack orientation, and crack resistance characteristics. The theoretical formulas derived satisfactorily describe experimental findings on the pure torsion of thin-walled cylinders with planar circular internal cracks. References 6: all Russian.
[151-1386]

UDC 620.193.4

CORROSION OF TITANIUM AND ITS ALLOYS UNDER CONDITIONS OF PURIFICATION OF TEREPHTHALIC ACID

Moscow ZASHCHITA METALLOV in Russian Vol 16, No 3, May/Jun 80 pp 323-327
manuscript received 10 Oct 77

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[Abstract] One way to purify terephthalic acid is recrystallization in concentrated acetic acid at temperatures up to 300° C. Promising materials for the hardware used in this technique are titanium and its alloys. To determine the best materials, corrosion tests were done on VT1-0, AT3, OT4-1, AT6, 4205, St1, 4200, 4201 and 4204 alloys. Acetic acid concentrations were 99.8, 98 and 90% and the total pressure of acid vapors and air or acid vapors and nitrogen was 31-38 atmospheres for 80 hours. Corrosion was determined by weighing, the depth of oxide films and gas-saturated layers was determined by measuring microhardness, and the composition and structure of the films was determined by electron diffraction analysis. The nature of corrosion fracture was determined by microstructural analysis. It was found that the corrosion resistance of titanium alloys in glacial acetic acid is satisfactory only in a nitrogen atmosphere, and is increased by an order of magnitude when 2-10% water is added to the acid. The best combination of thermal stability, strength and corrosion resistance in 98% and 90% acetic acid at 270° C in gaseous and liquid media in atmospheric air was shown by AT-3 alloy. Figures 2; references 11: all Russian.
[163-6610]

UDC 620.194

ON THE PROBLEM ON THE KINETICS OF CORROSION CRACKING OF MAGNESIUM ALLOYS

Moscow ZASHCHITA METALLOV in Russian Vol 16, No 1, Jan 80 pp 38-42
manuscript received 5 Dec 78

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[Abstract] A method was developed for determining the point of transition from the incubation period to the period of avalanche-like fracture using magnesium alloys MA2-2 and MA2-1. This method was based on mathematical analysis of experiment potential-time and elongation-time curves. According to the experimentally found changes of potential and elongation during corrosion cracking of these two alloys under static load in a solution of 30 g/l NaCl + 80 g/l $K_2Cr_2O_7$, equations were obtained which describe the fracture kinetics including the incubation and crack development periods. Experimental data and mathematical expressions were obtained for the relationship of potential to elongation where for a more ductile sample a greater elongation corresponds to the unity of potential growth. Figures 4; references 4: 1 Russian, 3 Western.
[86-6368]

CREATING THE CONDITIONS FOR EXPANDING THE RAW MATERIALS OF THE URALS

Sverdlovsk URAL in Russian No 5, 1980 pp 121-125

[Article entitled "A Reliable 'Rear Guard' for Industry" by M. Mutalov, senior lecturer at the Moscow Technical Institute (Ufa Branch), candidate of geological-mineralogical sciences]

[Text] The mining complex in the Urals has existed for more than twenty years. There has been time enough to deplete many of the mineral deposits. Some of these deposits are already in their final working stages. Does this mean that the Urals no longer have any prospects for raw materials? Of course not! Are there no examples of areas that seemed to have been carefully explored by geologists long ago, but in which new raw material resources were later discovered?

An interesting and controversial article by Professor A. A. Malakhov "Are the Urals depleted?" focuses on theoretical questions regarding the origin of the Ural mountains, the precise understanding of which is necessary in searching for mineral deposits as well as for efficiency in geological prospecting work in general. The problem, as it were, is presented bluntly, and there are a whole host of difficulties to overcome in order to solve it.

However, it would be a serious mistake to think that the problem of raw materials in the Urals can be solved only by more theoretical studies and geological exploration. No, it is necessary to integrate geological, geological-economic, and technological work. Only a solid association of geologists, minerologists, metallurgists, technologists, and economists can create the conditions necessary to broaden the raw materials base of the area by total and optimum use of the mineral ore. Following the main thesis of the article by Professor A. A. Malakhov, concerning the fact that the Urals are not yet depleted, I want to express some ideas using as an example the trans-Ural Bashkir, where there are deposits of nonferrous and noble metals, as well as works for processing their ore.

Although Mashkir is in the Povolzhsk economic region, the geological structure of the mountainous par· clearly indicates that it is the offspring of the Urals. For this reas›n, the problem under discussion, concerning the provision of the diversified industry in the Urals with raw materials, has a direct bearing on our Republic as well.

Over the last 15 to 20 years, a series of large deposits of copper pyrite and polymetallic ores have been discovered in the trans-Ural Bashkir area. The large deposits among these are the Uzel'ginsk and the Podol'sk copper pyrite deposits. Five other deposits have been located near them and the search continues. The outlook is very promising. These ores form a reliable raw material base not only for industry in Bashkir, but also for all the branches of nonferrous metallurgy in the Urals. The outlook is supported by the discovery of a series of ore-bearing veins at the edges and deep levels of already proven copper pyrite deposits. To be honest, geologists in Bashkir have only very recently learned how to study deep levels, say, at a depth of 800 to 1000 meters and more. Why, two decades ago the average depth of boreholes did not even attain 150 meters! What does this indicate? It indicates that the eastern side of the southern Urals (the Bashkir area) is just beginning to reveal its buried treasure. Professor A. A. Makhalov is correct when he begins and ends his article with the words: "What is buried there? This is not an idle question, but a vitally important question for the economy of the Urals." In this respect, the trans-Ural mineral resources of Bashkir, even in the sense of the basic hypothesis about the origin of the Ural mountains, support the idea that the Urals "have not yet spoken their final word." And, they will play a significant role in the foreseeable future as the "mainstay of power, its getter and forger."

Mineral resources are one of the major elements of the national wealth. They determine in many ways the economic potential of a country. This truth does not require any discussion.

In our country, the rate of growth in mineral extraction is more than one-and-a-half times greater than the increase in the annual world consumption of mining output. Since it is necessary to look for minerals in uninhabited places and at great depths under less favorable mountain-geologic conditions and with a lower content of useful components, the result is a large increase in expenditures on prospecting, mining, and processing of raw materials. Let me venture a few numbers. Expenditures on geological prospecting for the years from 1950 to 1975 increased by a factor of six and in 1975 they constituted 4 billion rubles. They continue to increase annually by 5 to 8 percent. In the Urals, the cost of increasing the supply of, for example, iron ore by one ton [Translator's note: here, and elsewhere in this article, the author is most likely referring to the metric ton] increased during the Ninth Five-Year Plan by a factor of 1.6 in comparison with the Eight Five-Year Plan. For the period from 1970 to 1978, the cost of extraction of the most important types of minerals increased almost by 10 percent. If iron ore is considered in particular, then this quantity constituted 16 percent for the country as a whole and 21 percent in the Urals.

The decrease in the content of the basic metals in the extracted ore has now stabilized. Therefore, expenditures on ore concentration have also increased sharply. The expenditures are increasing and the profitability of mining production decreases proportionately, as does the profitability of manufacturing. Thus, inevitably, the existing trend can only be changed by a well-thought-out reorganization of the established methods for economic exploitation of the mineral deposits.

Until, recently, when capital was strictly limited and the country was in need of the most important metals, mineral processing technology was concerned with a single goal: more complete extraction of the basic component. With a rapidly developing economy, when the rapid growth in scientific-technical progress has greatly increased the technical level of manufacturing and has led to new requirements, it became not only useful but necessary to use a larger fraction of the extracted raw material, that is, to make more efficient and complete use of the raw material.

According to scientists (M. A. Sergeyev, O. A. Romanova, and V. N. Leksin), the additional reserves released by total recovery of the available mineral resources will increase the economic potential of mining areas by 25 to 30 percent, which would provide the national economy with an additional production of 30 billion rubles. This figure, as you can see, is very impressive.

An important property of most mineral resources is their composite structure, which greatly influences the productivity of the industrial raw material base. The overwhelming majority of deposits in the Urals are also intrinsically composite. They contain diverse metallic and nonmetallic minerals, both as basic components and as impurities. For this reason, the most important condition for effective development of production based on optimum use of raw material resources is to make sure that the total recovery of useful minerals corresponds to the composite nature of their deposits.

The release of reserves, as a result of total recovery of mineral resources, has an economic value of tens of millions of rubles annually.

But, there are definite difficulties with this approach: narrow specialization of the mineral extracting and processing enterprises, weak economic incentive for the enterprises to make the transition from an established production process to total utilization of raw material resources, incomplete technical knowledge concerning the composite forms of the raw material, absence of comprehensive prospecting for most of the deposits that are being developed and prepared, as well as of an estimate of the economic effectiveness of their total development, and the lack of a solution to a series of other organizational and economic planning problems.

The importance to the government of the problem being discussed became clear as a result of special All-Union conferences (Moscow in 1970 and 1976; Sverdlovsk in 1977 and 1979).

The decisions made at these forums can be summarized as follows:

--it is necessary to put an end to the narrow specialization of mining enterprises;

--all mining enterprises should be set up (at least in developing new mineral deposits) according to the type of combined production (associations), based on an over-all design and optimum extraction of all useful minerals in a given deposit, along with the waste products of ore concentration.

This type of mining organization will inevitably require that they be concentrated or united in a single region. Only this type of centralization of control over the entire mining industry in the Republic can provide the most complete and effective utilization of mineral resources.

Bashkir is distinguished by its high concentration of mineral resources. Of particular significance are the deposits of copper pyrite ores in the trans-Ural area of the Republic, as mentioned above.

The Uchalin ore-concentrating, Bashkir copper-sulphur, and Buribayevsk ore-management complexes form the basis for the development of some of the copper pyrite deposits in the Republic. The annual extraction of copper pyrite ores at these enterprises constitutes a large fraction of all the mining in the Urals.

An innovation in the concentration of copper pyrite ores increases the over-all recovery to five chemical elements. At the same time, individual ores contain up to forty elements and half of them have commercial interest. If thirteen elements are included (taking into account rare and trace elements), then the recovery factor for pyrites will constitute 40 to 45 percent. In this case, 75 to 83 percent copper is extracted into the copper concentrate, 70 to 75 percent zinc is extracted into the zinc concentrate, and 75 percent sulphur is extracted into the pyrite concentrate. Meanwhile, the pyrite concentrate, the output of which constitutes 80 to 85 percent of the entire ore body, is used by numerous chemical plants only as a raw material for the production of sulphuric acid. The pyrite cinders obtained in this process are not used in the USSR, since no sufficiently efficient technology has been developed. Meanwhile, the potential value of a ton of this product is estimated at 400 rubles. The ministry for the chemical industry in the USSR has made use of this most valuable raw material in a peculiar manner: selling it for the production of nonferrous cement for 1 ruble 20 kopecks per ton of pyrite cinders! And Bashkir carries most of the economic loss.

This is why there is such great interest in the new technology, referred to as the total processing of pyrite concentrates in a two-step cyclone setup, developed at the Institute of Metallurgy of the Ural Scientific Center of the USSR Academy of Sciences with the participation of the All-Union Scientific-Research Institute of Metallurgical Heat Technology

in Minchermeta USSR. It is not the pyrite cinders that are reprocessed, but the pyrite concentrates. This eliminates the expenditure of fuel on repeated heating of cinders and decreases the accumulation of wastes in dozens of sulphuric acid plants in the country. This year, the quantity of pyrite cinders will attain 45 million tons in chemical plants. It is also important that pyrite concentrates from Bashkir were taken as the starting raw material for the development of the new technology. The annual economic gain, without taking into account the production of sulphuric acid, will constitute about 11 rubles per ton of pyrite concentrate. From here, it is not difficult to determine the economic loss to the national economy due to inefficient recovery of copper pyrite ores in Bashkir. In addition, the fact that the invested capital will be recovered within one to two years should be taken into account. At the same time, a profit of 1,15 rubles for each ruble of capital expenditures could be obtained.

What, then, must be done in order to put this promising technology into use? On the basis of their laboratory studies, metallurgists have conducted pilot tests of the total processing methods for pyrite concentrates from Bashkir. In order to verify these results, it is necessary to make a commercial test at one of the ferrous metallurgy enterprises in Bashkir, for example, in the city of Siba. Here, metallurgists propose to conduct tests on obtaining elementary sulphur when processing pyrite concentrates. If the results are positive, then it will be possible to consider organizing a centralized processing operation for pyrite concentrates by expanding the pilot plant setup into a large combined enterprise (a plant within the Bashkir copper-sulphur association). In this case, Bashkir will produce fluxed iron ore raw material as well as ferrous, noble, and rare metals from sublimates. The iron ore can be brought to the ferrous metallurgy enterprise in the Urals, in particular, to the neighboring metallurgical complex in Magnitogorsk, currently operating on delivered raw material, elementary sulphur from the sulphuric acid plants in the European USSR. In this case, the volume of railroad traffic can be decreased by a factor of three, which is very significant in view of the current level of activity in railroad transport.

It is necessary to create a specialized laboratory that should become the brain center for the pilot plants, a prototype for the total production with no waste products (few wastes) based on the total processing of pyrite concentrates and, later, of multicomponent ores in the Urals. The usefulness of such a laboratory was decided by the office of the Bashkir oblast committee of the Communist Party of the Soviet Union (1975) and by the All-Union (1976) and Regional Ural (1977) Conferences on the problems of the total utilization of mineral deposits. The organization of such a laboratory has been assigned to the Bashkir branch of the USSR Academy of Sciences. Assigned.... But, the branch has not yet taken any action; dozens of scientific-research institutes for oil and gas operate in the Republic, while there is not even a siggle institute concerned with the over-all study of ore deposits, specifically, the technology and economics of processing multicomponent sulphide ores. All of this conflicts with the urgent need to conserve natural resources and to use them efficiently.

It seems that now, on the eve of the completion of the Tenth Five-Year Plan and on the threshold of the Eleventh, when the material-technical base of the scientific institutions has broadened significantly, the output of the mining and processing operations in the Republic has noticeably increased, and the qualifications of the labor force and engineering-technical personnel are unequalled, these problems should be reconsidered and they should be placed first on the agenda.

[172-9638]

9638
CSO: 1842

BELORUSSIAN SSR TAKES STEPS TO HASTEN DEVELOPMENT OF POWDER METALLURGY

Minsk PROMYSHLENNOST' BELORUSSII in Russian No 4, 1980 pp 48-52

[Article by O. Roman, director of the Scientific-Research Institute of Powder Metallurgy, honored scientist and engineer of the Belorussian SSR, professor, and P. Vityaz', candidate of technical sciences, entitled "The Effect of New Solutions"]

[Text] Appearing at the November [1979] Plenary Session of the Central Committee of the Communist Party of the Soviet Union, Comrade L. I. Brezhnev pointed out that there are many new directions in machinery construction and in metallurgy, in which it is possible to make large ultimate gains for the national economy at the lowest possible costs. In particular, he stimulated interest in the necessity of developing powder metallurgy more rapidly. This problem was also raised at the Nineteenth and Twentieth Plenary Sessions of the Central Committee of the Communist Party of Belorussia.

The selection of material presented below describes what is being done in our Republic for the future development of powder metallurgy and what kind of difficulties are being overcome in the process.

In 1826, the Russian scientist P. G. Sobolevskiy published a treatise on a chemical-mechanical method for obtaining malleable platinum. The technological methods that he used in essence consisted of the elements of modern powder metallurgy. Today, powder metallurgy can satisfy many of the requirements of modern industry. However, as in the past, the essence of the method consists of obtaining metallic powders, pressing them, and annealing in a controlled atmosphere. A part, made in this manner, often has no equal with respect to durability and strength and, as a rule, does not require further mechanical working.

Other advantages of powder metallurgy include the fact that it is waste-free and it is not labor intensive. Let us recall the traditional manner in which a metal is used. One ton of finished parts requires more than one-and-a-half tons of stock. Working by cutting produces more than eight million tons of steel shavings and up to twenty thousand tons of shavings of titanium and its alloys. The methods of powder metallurgy, on the other hand, require not more (and sometimes less) than a ton of powder in order to produce one ton of manufactured product. In addition, the stock of technical equipment is greatly reduced and simplified. Consequently, the work force is also reduced. Productivity doubles in comparison with casting under pressure, pressure working, and cutting. It has been established that 1.75 million rubles are saved with the transfer of every thousand tons of manufactured product intended for machinery construction out of ferrous metals into production by the methods of powder metallurgy and up to 2.2 million rubles in the case of nonferrous metals. One-hundred-ninety workers and eighty metal-working machine tools are freed, and up to 2,900 tons of rolling or casting stock are eliminated. Components prepared from powders are two to three times stronger than components made of gray iron, widely used in machinery construction. A no less important advantage of powder metallurgy is the possibility of obtaining new materials with predetermined properties. These and many other advantages of powder matallurgy have led to its wide use in many branches of industry. In our Republic, the practical development of powder metallurgy began with the powder metallurgy laboratory at the Belorussian Polytechnic Institute, subsequently changed into a scientific-research institute. Together with the study of theoretical questions, many new materials and technological processes, successfully introduced into industry, were developed here. Let us present several examples.

During the Tenth Five-Year Plan, a phenomenological theory of the deformation of simple bodies with shock waves was formulated at the Institute. This permitted analysis of the dynamic compression of powdered materials and it permitted optimization of the conditions for shaping powders with the energy of an explosion. The method of hydrodynamic pressing was based on this theory. The use of powder as the energy carrier allowed the creation of essentially new types of plants, called hydrodynamic plants. In comparison with hydrostatic plants, such plants require less metal; they do not require complicated and expensive pumps, duplicating machines, or a complex pressing system. At the same time, they are reliable, economical, and efficient. We were also able to establish the power and structural parameters of the plants and to develop, together with the All-Union Scientific-Research Institute of Metallurgical Machinery Construction, a system of machines in the laboratory and a pilot plant with a working chamber having a diameter of 350 mm, a height of 1,200 mm, and a pressure from 0.4 to 1.5 GPa (up to 20 thousand atmospheres). The structural parameters of the machines and the technological regimes for shaping powders, as a function of the type of powder, plunger mass, size of charge, compressibility of the working fluid, properties of the material being formed and so on, were optimized with the help of an electronic computer.

In addition, detailed information was obtained concerning the kinetics of the process as a function of time. As a result, a series of technological processes using hydrodynamic machines has been developed. An example of an assimilated technology is the production of large filtering elements, constituting porous tubes (diameter ranging from 40 to 120 mm, length ranging from 120 to 500 mm, wall thickness ranging rom 3 to 10 mm, and pore dimensions ranging from 3-5 to 100 μm), out of titanium powders. The filters are intended for aeration, separation of suspensions, and cleaning of gas and liquids of suspended particles. They can be used successfully in nonferrous metallurgy and chemical, food, and medicinal production. For example, in 1979, in order to biologically clean waste water, metallic filters were installed at the Novopolotsk refinery which led to a savings of 262 thousand rubles for each aeration tank. Now, these filters are being installed at the Novopolostk manufacturing complex "Polimir", at the Syzransk refinery, and at several plants in Kuybyshev and Ufa. Together with the Belorussian Design-Technological Institute of Municipal Services, we are working on the use of porous materials for biological cleaning of ordinary sewage, for which new, improved filters are being created. Work is also being done on the use of aluminum powders and on the porous structures that can be made from such powders.

The Institute staff has developed the principles for modeling porous structures, which allows for obtaining materials with the required pore distribution. On this basis, the average number of pores was increased by 25 to 32 percent, the uniformity of gas permeability was increased by 30 to 35 percent, and the magnitude of the capillary potential was increased by 15 to 20 percent. This significantly improved the quality of the filters. The experimental technology of preparing porous materials in the form of disks, plates, tubes, machine tools, and so on out of bronze powders with average pore sizes ranging from 2 to 200 μm, air permeability ranging from 10^{-6} to 10^{-13} cm^2 and porosity ranging from 30 to 60 percent, has been assimilated. All of these products show improved performance. This improvement is the result of control over the pore distribution.

The materials created are widely used for filtration of gases and liquids, in heat-exchange equipment, and so on. Examples include their successful use in the Mogilevsk complex "Khimvolokno" for determining the quality of a suspension of titanium dioxide and carbon black, uniform cooling of elementary filaments in an air flow, filtration and homogenization of a spinning alloy. It is now possible to eliminate buying some manu actured parts abroad, which in 1979 saved the en erprise more than 200 thousand rubles. In the immediate years ahead, this savings will increase several times.

It is impossible to imagine a machine without sliding bearings. Such bearings are most often made out of brass, bronze, and babbitt. They are expensive and do not last long. Antifrictional, porous materials developed by us last one-and-a-half times longer, withstand higher sliding speeds and loads, and are much less expensive. These materials are prepared

from iron powder and graphite (other alloying components are sometimes introduced). On annealing, part of the graphite interacts with the iron, forming a very strong base, while the remaining free graphite forms a solid lubricant. In addition, the pores take up 15 to 25 percent of the volume of the material, allowing for saturation of the part with oil, which during operation comes into contact with the shaft and together with the graphite provides self-lubrication.

Frictional materials necessary for brakes, clutches and so on are very effective products of powder metallurgy. Their use significantly increases the performance and longevity of these components.

Many other materials, satisfying the requirements of modern technology, have also been created at the Institute. In so doing, the functional dependence of wear on the physico-mechanical parameters and content of the components has been established. On this basis, an analytic dependence of wear on frictional powdered materials operating with lubrication has been proposed. Such a fundamental approach has led to the creation of the M-106 and M-140 copper-based materials, which have better technical and economic properties that the MK-5 material used in the past. They have a friction coefficient in oil varying from 0.06 to 0.12, limiting specific load allowed in operation of 60 kg/cm^2, and a sliding speed up to 30 m/s, withstanding temperatures of 300° C on the rubbing surface. The new materials have proved themselves in transmissions for power take-off boxes, safety clutches in lift trucks, and in automobile fluid transmissions. Thus, the use of a disk with linings made of the M-106 material in the brakes of a DZ-98 grader decreased the braking distance of the machine by a factor of 2.5 and increased the useful life of the component by a factor of 10 (!). The overall annual economic gain as a result of the use of disks and linings made of the developed copper-based frictional materials has exceeded one million rubles.

Iron-based frictional materials have also been developed for operation in oil. They have improved heat resistance (up to 800° C on the rubbing surface) and strength, and they contain a minimum of costly and scarce components. A material was chosen as a frictional additive that interacts, during the annealing process, with the iron base along the contact surfaces. In order to increase the strength and corrosion resistance, this base is alloyed with nickel and copper. The coefficient of friction of this new material is twice as great as the coefficient for the MK-5 material, and the strength is two to three times greater than for MK-5. It is more durable and its cost constitutes about 15 percent of the cost of MK-5.

The new materials are undergoing testing in the clutches of tractors, vibrating rollers, and other machines. Pilot plant production of friction disks for various kinds of road-building machines, asphalt-surfacing machines, seam-cutting machines, and others has begun. Further work in the area of friction materials will allow increasing their performance and will realize an economic gain of tens of millions of rubles.

On the basis of theoretical studies of porous materials carried out at the Institute, molds are also being successfully developed for plastic shaping of ceramic parts. In comparison with plastic, they are one to two orders of magnitude stronger (4-10 kg/mm^2), more heat resistant (above 300° C), and have good thermal and electrical conductivity, which allows for the formation and drying of porcelain parts in an essentially different manner. These materials have been tested at the Minsk, Dmitrov, and Tashkent porcelain plants; the turnover of the molds made of powders is not less than 8,000 cycles, and they can be restored. These characteristics can, in the future, be improved by a factor of two to three. The economic gain of using molds made of powders, due to the decrease in the intrinsic cost, constitutes on the average 6,000 rubles per 1 million porcelain parts or 3.6 million rubles for the total an ual production. The final economic gain will be much greater, since there will be a possibility of making high-productivity aggregates for forming and drying ceramic parts.

A great deal of attention is directed by the staff of the Institute toward developing a theory for pressing of powders and deformation of powdered stock by static loads at room and higher temperatures. Using the concept of mean-squared deformations and strains, analytical relationships have been obtained for the work and pressure of compaction at the first stage of the process, taking into account the strain hardening of the base metal and losses to external friction. It has been established that the compacting pressure is determined by the resistance of the material to deformation and by external friction; it is practically independent of the starting density of the s ock. Plastic deformation of the stock can be viewed as a process in which the first stage is characterizdd by compaction of the material and the second stage is characterized by its flow into a ring-shaped gap. On the basis of these studies, a method has been proposed for production by cold extrusion in powdered stock with subsequent chemico-thermal working in the working cavity of a die in the second precision class. The utilization factor of the material in this case is close to unity and the labor intensity of the manufacturing process is decreased by a factor of 5 to 10 in comparison with the traditional methods. The intrinsic cost of the new tool has decreased by 3 to 15 rubles per unit. The durability of the instrument, when used for impact extrusion of nonferrous metals, is 2 to 5 times greater than for steels; it withstands up to 25 to 60 thousand impacts. The new tool, prepared by the pilot plant at the Institute, is used at the Minsk industrial complex "Gorizont" imeni V. I. Lenin, at the Orshan tool fabricating plant "Krasnyy Borets", at the Shaulyaysk and Simferopol'sk television plants, and other enterprises. The annual economic gain exceeds 750 thousand rubles.

Based on theoretical studies of the plastic cold deformation of powdered stock, a method has been developed for preparing parts with complex shapes from plastic materials, for example, radio-frequency connectors. The parts obtained in this manner have a residual porosity of less than 1 percent and they have high physico-mechanical properties, precision, and a clean

surface. The utilization factor of the material in this case attains 0.9, as compared with 0.3 for the existing manufacturing technology. In addition, there is now the possibility for automating production, which reduces the labor intensiveness by a factor of 3 to 4 and the intrinsic cost by a factor of 2 to 3 and increases the productivity by a factor of 10. The new technological process is basic to modernization of many enterprises in this country. As a result, the production of many new types of parts will increase and a large quantity of brass will be conserved. The expected economic gain is estimated in the millions of rubles.

Comparatively recently, theoretical and practical studies of the reduction and strengthening of machine parts by plasma and gas-flame spraying have begun at the Institute. A few words describing what this is all about follow.

Protective coatings sharply decrease the expenditure of ferrous and nonferrous metals, increasing the quality and longevity of machines and mechanisms, and increasing productivity significantly. Complete utilization of these advantages promises to bring an enormous gain to the national economy. In fact, in the automobile industry alone expenditures on the production of spare parts in 1980 will constitute, according to preliminary estimates, 2 billion rubles, while the expenditure of metal on manufacturing spare parts in the trucking industry is beginning to exceed that on the production of new trucks. Thus, increasing the time between service by a factor of 1.5 to 2 will lead to an annual savings of several billions of rubles.

Here is a specific example of the effectiveness of protective coatings. The durability of cast iron crankshafts for GAZ-24 engines, after plasma working with the use of carbon steel, increases by 40 percent, and by a factor of 3-4 for Kh-13 chrome steel. The cost of the reduction is about 5 rubles (a new crankshaft costs 16 to 24 rubles). It is just as profitable to deposit protective coatings on many other types of parts as well: camshafts, brake drums, and so on.

However, there are many organizational and scientific-manufacturing problems facing the widespread introduction of the gas-flame and plasma methods of deposition. For example, how should protective coatings be worked? In the immediate years ahead, it is necessary to carry out studies on the theoretical foundations of the processes involved in depositing coatings, their classification, and working, and to create the necessary equipment, transfer machines, and standards, and to make technological recommendations. It is true that the staff at the Institute has already done much for this plan in recent years, but even more remains to be done.

On the whole, the staff at the Institute in 1979, carried out work on four union programs, six programs in the Republic, three industry programs, and three union topics, approved by the Goskomitet (State Committee) of the USSR on science and technology. These programs were bolstered by 68 contracts with industry. The novelty of the studies carried out is illustrated

by the following data. In 1979 alone, 110 claims were made for inventions, 40 patents were obtained, and 65 favorable decisions for issuing them were handed down. The work at the Institute has been awarded one gold, 8 silver and 22 bronze metals. The practical return of the studies is also constantly increasing. For example, in the present Five-Year Plan, it is increasing annually by more than 30 percent. In 1980, it is estimated that the economic gain from using the developments in industry will be 9 million rubles. At present, a comprehensive program for developing powder metallurgy and protective coatings is being developed for the Eleventh Five-Year Plan. Steps are being taken to complete the material-technical base of the scientific-research institute and its SKTB [special design-technological office] with test production and a pilot plant for powder metallurgy.

The data presented above indicate the fact that on the whole the staff at the Institute is keeping up with the times. Of course, it was necessary to make great efforts to set up contacts with industry, before the optimal forms for the organization of scientific research work were found. One of the most important steps in this direction is the creation of the SKTB with experimental production.

The Institute has been reorgnnized in order to concentrate the efforts of the staff along the most important scientific-technical directions and to systematize the research process. A division for physico-chemical research has been created with metallo-graphite and chemical laboratories as well as a laboratory for studying thin structures. The unique instruments of interest to all the departments are collected here: x-ray diffractometers with high-temperature and low-temperature attachments, electron and scanning microscopes, a microanalyzer, television and high-temperature microscopes, an atomic adsorption spectrophotometer, and many other instruments and setups. The most important means for collaboration between this department and the other departments in the Institute have been worked out. These include the completion of studies applying established techniques using only the efforts of the department; carrying out simultaneous studies by co-workers in the physicochemical department and the ordering department, including development of new methods, finding new laws, and creating new materials; carrying out studies on order by the main departments (in this case, the ordering department gives the order, while the staff in the physico-chemical research department carries out the order). These techniques for organizing scientific research have been effective and will be improved in the future. The second form has been the most successful. It allows for solving operationally many complex problems in the area of materials technology.

At the same time, specialized equipment has been concentrated in the main subdepartments. Thus, the pulsed loading and explosive welding departments have appropriate equipment and setups for studying compaction processes for powdered materials in hydrodynamic setups. The tool-making materials department has the necessary instruments and setups for annealing in a vacuum and so on. New instruments and setups are being created. Thus,

techniques have been developed in the porous materials laboratory for determining the wetting angle for porous materials, the capillary potential, and the thermo-physical properties, as well as instruments for studying them.

In other words, the Institute has a good material-technical base, which is used not only by our staff, but also by instructors at the Belorussian Polytechnical Institute and many other institutes of higher learning. Many problems are solved in collaboration with scientists at academic institutes.

In talking about the organization of scientific research at the Institute, the role of metrological work should not be overlooked. This work controls the use of instruments and experimental setups and also develops new instruments and systems for automating the research work. It should be noted that we were able to solve the first problem independently by creating a metrological group. It not only checks but also maintains all instruments and experimental setups (including those that are imported) in working order. However, we could not solve the second problem, In order to create new instruments and systems for automating research work, it is necessary to specialize the individual institutes in our Republic. Much can be done, for example, by the Minsk Radiotechnical Institute and the Belorussian State University, which have enough qualified specialists. Possibly, appropriate centers should be created at these institutes with the necessary material and technical support.

In order to stimulate research in powder metallurgy, it is necessary to provide a system for training specialists. The participation of students in the research and development work at our Institute has been very successful. As a result, after they complete their work at the institute of higher learning, they can perform their own research and introduce their results. There are many examples of students from the mechanical-technological, machinery construction, and the engineering-pedagogical faculties of the Belorussian Polytechnic Institute, who having been introduced to research in powder metallurgy, completed their course work and diploma projects, and then continued their work in this area. Many of them are candidates of technical sciences and head subdepartments in our Institute. This trend is continuing.

There are definite difficulties. As a minimum, two to three specialized laboratories are required, and as yet there is not one such laboratory, although we are prepared to equip them with modern equipment and instruments. In order to train qualified specialists in new fields, the leadership at the Belorussian Polytechnic Institute and the administration of the mechanical-technological faculty must find a place under specialized laboratories for a "Powder Metallurgy" department.

Each year, five to six candidates' dissertations are defended in powder metallurgy. In all, more than 50 candidate and four doctoral dissertations have been defended. Taking into account the needs of powder metallurgy, this is not enough. For this reason, the administration of the Institute has assumed control over preparing doctoral dissertations. All the prerequisites necessary for the preparation, as a minimum, of a single doctoral dissertation each year are available.

One way to deepen and broaden fundamental research and to accelerate its realization in the national economy is to strengthen organization and economic ties between the learning process, research work, and manufacturing. The experience of the Ye. O. Paton Institute of Electrical Welding of the USSR Academy of Sciences, as well as our own, over a period of many years has shown that combining the research organizations and enterprises that are constantly and intimately connected with each other in the course of creating new techniques, technology, and materials under one "roof", allows for the most rapid assimilation of the most complex scientific-technical developments into manufacturing. The creation of the Belorussian Scientific Manufacturing Association for Powder Metallurgy based on the Scientific-Research Institute of Powder Metallurgy, the SKTB with experimental production and a pilot plant for powder metallurgy has opened up great possibilities in this plan. At the same time, it is very important that science and its subdivisions remain the dominating force. However, this problem cannot be solved without a well-equipped scientific-research and test-experimental base. In order to create such a base, we used the means provided by interested ministries and departments. During the years of the Tenth Five-Year Plan, the basic funds of the Institute have increased by more than a factor of 4 and the volume of completed work by a factor of 2.5. The efficiency for introduction of new developments has increased by a factor of 4.5 and the return on each ruble spent has doubled. In 1979 alone, contract work has increased by 37 percent and the cost of each contract has increased by 30 percent. This also indicates the increased quality of the research.

Appearing at the Nineteenth Plenary Session of the Central Committee of the Communist Party of Belorussia, Comrade P. M. Masherov stated: "We are talking about new and important progress of a scientific-technical nature... And, any efforts in this direction, in particular, the decision to construct a plant to produce a series of parts for machinery construction out of powdered materials, should be considered only as a beginning to a large promising business. New scientific developments and new, more powerful, enterprises are needed." This obliges the staff of the Scientific-Research Institute of Powder Metallurgy to accelerate its efforts in creating new methods for obtaining parts out of powders and to ensure their assimilation into industry.

[173-9638]

9638
CSO: 1842

UDC 548.73

TEXTURE OF BORON NITRIDE MATERIALS

Kiev POROSHKOVAYA METALLURGIYA in Russian No 4, Apr 80 pp 41-46 manuscript received after revision 27 Oct 79

BURAVOV, A. D. and D'YAKONOV, B. P.

[Abstract] The texture of several boron nitride materials was studied by the diffractometric recording of the intensity distribution from plane (002). The texture functions of the materials were represented by the relationship $T_i(\phi) = A_i\cos 2\phi + B_i$. According to the ratio of the maximum and minimum intensities the degree of texturing of each material was determined. According to this indicator the materials were arranged in the following order: pyrolytic (22.75), hot pressed (3.46), powder (1.64), powder with a silico-organic binder (1.21), reaction powder (1.11) and BN produced by slip casting (1.06). On the basis of a model of uniform uniaxial compression of a material an equation was produced for the intensity of planes (002) in relationship to the degree of compression k and the angle of observation ϕ relative to the direction of packing. It was established that the degree of uniform compression k can serve as the material texturing indicator. Figures 3; references 4: 3 Russian, 1 Western.
[133-6368]

UDC 669.17.621.785.16

DEPENDENCE OF PHASE TRANSFORMATION AND OF PHYSICO-MECHANICAL PROPERTIES OF THE VT16 TITANIUM ALLOY ON THE PARAMETERS OF RAPID ELECTROTHERMAL TREATMENT

Minsk IZVESTIYA AKADEMII NAUK BELORUSSKOY SSR, SERIYA FIZIKO-TEKHNICHESKIKH NAUK in Russian No 4, 1979 pp 23-28 manuscript received 14 Dec 78

BODYAKO, M. N., GORDIYENKO, A. I. and SHIPKO, A. A., Physico-Technical Institute, Belorussian SSR Academy of Sciences

[Abstract] A study of the VT16 titanium alloy (2.5% Al + 7% Mo) was made to determine the dependence of its phase transformations and mechanical characteristics on the heating rate and temperature, and on the cooling rate. Rod specimens in a metastable initial state were produced by preliminary quenching after heating to ($\alpha + \beta$)-phase and β-phase temperatures. Subsequent water cooling did not change the phase composition. A $\beta \rightarrow \alpha''$-martensite transformation occurred during quenching, after the critical β-phase concentration had been reached at 750° C. No sharp increase of plasticity during formation of the α''-phase was noted. Faster heating rates required heating to higher temperatures before quenching for formation of the α''-phase with lowering of the yield point and raising of the tensile strength. Maximum hardening (up to 110 kgf/mm^2) was attained after rapid heating (25-100° C/sec) to 850-1050° C and subsequent air rather than water cooling. While rapid heating lowered the yield point (down to 72 kgf/mm^2) and raised the temperature at which a decrease of plasticity occurred, slow air cooling raised the yield point again (up to 104 kgf/mm^2). Rods with an adequate tensile strength (90-98 kgf/mm^2) and a high plasticity (ψ = 72%, δ = 22%) were obtained by rapid heating to β-phase temperatures (900-950° C) and subsequent quenching. Figures 4; references 8: all Russian.
[153-2415]

ON REVEALING THE BETA-GRAIN BOUNDARIES IN TWO-PHASE TITANIUM ALLOYS

Moscow ZAVODSKAYA LABORITORIYA in Russian Vol 46, No 4, Apr 80 pp 339-340

BODYAKO, M. N., GORDIYENKO, A. I. and IVASHKO, V. V., Physico-Technical Institute, BSSR Academy of Sciences

[Abstract] A method was tested for revealing the grain boundaries of beta-titanium alloys in order to better measure grain size. The method consisted of heating samples to 5-40° C above the martensite transformation temperature at the rate of 10-300° C/sec followed by water cooling. An additional treatment was carried out by heating the samples to 600-800° C for 1-15 minutes. The rapid heating leads to conversion of the two-phase structure to a single structure and prevents growth of the initial beta-grains. Use of an etchant of 1 part HF and 3 parts HNO_3 made it possible to preferentially decompose the metastable phases along the grain boundaries to show that a finely dispersed alpha-phase is precipitated along the beta-grain boundaries which interacts with the etchant to brightly decorate the boundaries. This method was found to be highly effective in studying the recrystallization processes in VT9, VT3-1 and VT18 alloys. Figures 1; references 2: both Russian.
[134-6368]

UDC 669.017

THE EFFECT OF TEXTURE ON THE MECHANICAL PROPERTIES OF ULTRAFINE-GRAINED MATERIALS

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 252, No 2, 1980 pp 351-355
manuscript received 25 Dec 79

KAYBYSHEV, O. A., KAZACHKOV, I. V., Ufa Aviation Institute imeni Ordzhonikidze

[Abstract] A study was made of the effect of texture of the properties of VT-6 titanium alloy, in which it is comparatively easy to achieve ultrafine-grained structure and the superplasticity effect. The alloy in the untextured state was produced by swaging, while that with the textured state was produced by a combination of swaging and rolling. The value of stress with different degrees of deformation was determined with an acuuracy of three percent and ultimate elongation was determined with an accuracy of five percent. The effect of texture on the properties of VT-6 alloy was investigated in specimens cut in the direction of the initial bar which coincides with the direction of rolling. The flow stress of the alloy in the textured state is lower than that in the untextured state. The plasticity of the alloy also varies significantly as a function of texture. The relative elongation of the textured alloy is

significantly higher than that in the untextured alloy and the differences also increase with a decrease of test temperature. The unusual effect of texture on the mechanical properties of the alloy is also retained over the entire investigated range of deformation rates. There is no anisotropy of flow stress and plasticity in the untextured alloy, while there is slight anisotropy of the flow stress in the textured state. Texture may affect the plastic properties of materials due to changes in the structure of grain boundaries under specific conditions of superplastic flow. Figures 4; references 9: 7 Russian, 2 Western.
[156-6521]

UDC 669.017

INFLUENCE OF THERMOCYCLING ON MODIFICATION OF THE PROPERTIES OF TITANIUM ALLOYS

Ordzhonikidze IVUZ. TSVETNAYA METALLURGIYA in Russian No 2, 1980 pp 114-119 manuscript received 2 Oct 78

ANUFRIYEV, V. P., BOGACHEV, I. N., deceased, and VEKSLER, Yu. G., deceased, Ural Polytechnical Institute

[Abstract] The results are given of an investigation of modification of the mechanical and physical properties of VT1-0, VT3-1 and VT-16 titanium alloys, as well as of their resistance to thermal fatigue, under the influence of thermocycling. Studies were made on samples 20 mm and 14 mm in diameter, for VT1-0 and VT3-1, and VT-16, respectively, and 70 mm long, cut from hot-rolled commercial rods and cast billets. Half of the samples of each alloy were annealed under standard conditions with a grain size after annealing not exceeding 30 to 50 microns, and the other half were annealed at 1250° C in vacuum for 5 hours with a resulting grain size of 6 mm for VT1-0, 3 mm for VT3-1 and 1,5 mm for VT-16. The thermocycling treatment consisted of rapid heating and sudden cooling. Heating was carried out in a salt melt with a heating rate of 15° C/sec and by means of high-frequency current with a heating rate of 100° C/sec to temperatures 50° C above and below the accepted recrystallization points and temperatures of the polymorphic $\alpha \rightleftarrows \beta$ and $\alpha + \beta \rightleftarrows \beta$ transformation and the samples were held at these temperatures from 30 sec to 20 min. Heat treatment was carried out repeatedly to 50 cycles and thermocycling was repeated to 100 cycles when thermal fatigue cracks did not originate after 50 cycles. The cooling rate was varied by using a spray, salt water and fresh water. Inasmuch as these titanium alloys are characterized by a rapid drop in the coefficient of linear expansion with a reduction in temperature, in one batch of samples after each cycle of heating, holding and sudden cooling, they were cold treated in a medium of liquid nitrogen. Metallographic thin sections were x-rayed in order to determine microstresses originating in thermocycling after 1, 3, 5, 10, 20 and 50 cycles. In

order to eliminate the influence of cold hardening originating in the process of mechanical preparation of the thin sections and samples, a 0,02-mm layer was removed by etching in a solution of hydrofluoric and nitric acid. X-ray investigations were made of the fine structure of these titanium alloys by means of a URS-501M x-ray ionization unit with the GP-4 attachment. A UPIP 60M bridge was used to measure resistivity. Mechanical properties were determined with a ZD 10/90 machine. It was found that thermocycling improves the mechanical properties of the alloys studied. For fine-grained alloys maximum strength characteristics are achieved in 10 cycles. For coarse-grained samples maximum strength and hardness are reduced and the maximum shifts in the direction of a lower number of cycles. The internal stresses originating in thermocycling are 1.5- to twofold greater than the level of stresses after 10-percent cold deformation for VT1-0 alloy and 15-percent for VT3-1 alloy. Deformation created by thermal stresses in thermocycling is caused by the anisotropy of the thermal expansion of titanium alloys and depends to a great extent on the maximum temperature of the cycle, whereby in the alloys studied the greatest stresses originate with a maximum cycle temperature of 930 to 950° C. When the maximum cycle temperature is higher than the recrystallization temperature, thermal stresses exceed the macroscopic yield stress and result in plastic deformation, which in turn results in thermal fatigue. Then thermocycling is carried out with a maximum cycle temperature below the recrystallization threshold, the alloys studied have high resistance to thermal fatigue. This study is the first time an investigation has been made of the mechanical properties and resistance to thermal fatigue of titanium alloys under the influence of the thermocycling treatment process. Figures 4; references 7: all Russian. [162-8831]

UDC 669.017

INFLUENCE OF INITIAL STRUCTURE ON HIGH-TEMPERATURE CREEP OF VT5 TITANIUM ALLOY

Ordzhonikidze IVUZ. TSVETNAYA METALLURGIYA in Russian No 2, 1980 pp 109-114 manuscript received 28 Jul 78

KARAKOZOV, E. S., RODIONOV, V. N., PESHKOV, V. V. and ORLOVA, L. M., Moscow Evening Metallurgical Institute

[Abstract] The results are given of a study of high-temperature compressive creep of VT5 titanium alloy with the following initial structures: coarse-grained, lamellar, fibrous and recrystallized, i. e., fine-grained polyhedral. The fibrous structure was produced by straining an alloy with a coarse-grained lamellar structure in the temperature region for existance of the alpha phase, i.e., 900 to 920° C. The recrystallized structure was produced by annealing an alloy with a fibrous structure at 960° C

for 180 min. Creep tests were performed by a procedure described in earlier studies (1977) in the temperature range of 800 to 975° C and pressure range of 0.1 to 2.5 kg/mm^2. Structural changes in the process of creep were studied metallographically. For VT5 alloy with a coarse-grained lamellar structure, over the entire range of temperatures, stresses and times studied, a steady-state stage of creep takes place. Curves are presented, showing the dependence of the logarithm of the creep rate on the pressure applied for VT5 alloy with a coarse-grained lamellar structure at different temperatures. These dependences are linear over the temperature and pressure range studied. The effective activation energy for processes controlling the creep of VT5 alloy with a coarse-grained lamellar structure was determined by plotting curves for the temperature dependence of the logarithm of the creep rate. In the temperature range studied these dependences are also linear. Also linear is the dependence of the effective activation energy for creep on the pressure applied. From these data an equation is derived for the rate of steady-state creep of VT5 alloy with a coarse-grained lamellar structure. Metallographic data show the presence of slip along boundaries of the initial beta grains. This slip is caused by intragranular strain created by the slip of alpha crystallites in relation to one another at interfaces. The creep of VT5 alloy with a recrystallized structure is less than that for a fibrous structure. For both the fibrous and recrystallized structures creep occurs according to one of the mechanisms of viscous flow. The microstructures of strained specimens with a fibrous and recrystallized structure show the characteristic existence of slip along grain boundaries. In the high-temperature region of 925 to 975° C slip occurs by means of intra- and intergranular mechanisms of plastic deformation. In the high-temperature range the creep of VT5 alloy with a fibrous and recrystallized structure is made possible by intergranular slip and is controlled by volumetric self-diffusion. The creep of a VT5 alloy with a coarse-grained structure is one order of magnitude lower than that of an alloy with a fibrous and recrystallized structure. With T = 925° C and P = 0.5 kg/mm^2, the following creep rates were arrived at: 10^{-6} for a coarse-grained lamellar structure, $2.9 \cdot 10^{-5}$ for a fibrous structure and 10^{-5} for a recrystallized structure. It is thought that these great differences are probably associated with the influence of the grain size of the intergranular structure and with the state of grain boundaries. For a coarse-grained lamellar structure with a pressure of less than 1.5 kg/mm^2 the value of the activation energy for creep is greater than the value of the activation energy for self-diffusion, i.e., in the movement of dislocations obstacles are encountered for the surmounting of which additional activation is required. It is suggested that the interfaces of alpha crystals can play the role of such obstacles. These interfaces are enriched with impurities and alloying elements which stabilize the beta phase, while alpha stabilizers are concentrated at the center of alpha crystals, representing a concentration inhomogeneity. An experiment was conducted to reveal the influence of this concentration inhomogeneity on the creep of VT5 alloy. It was demonstrated that clusters of impurity atoms in boundary zones impede the movement of dislocations, hamper diffusion processes along grain boundaries, and block slip along

boundaries, thus increasing the stress required for the continuation of deformation. Figures 6; references 11: 9 Russian, 2 Western.
[162-8831]

UDC 669.14'295

DEPENDENCE OF THE PROPERTIES OF A TITANIUM-STEEL BIMETAL ON THE CONDITIONS OF TITANIUM CONDENSATION

Moscow TSVETNYYE METALLY in Russian No 6, Jun 80 pp 81-83

TERESHKINA, R. I., GONCHAROV, T. S., MURAV'YEV, V. G., MANYAKIN, S. M. and KUPRIYANOVA, T. A.

[Abstract] A study was made to determine the characteristics of titanium condensation on a moving steel tape and their effect of these characteristics on the properties of the bimetal thus produced. Titanium was evaporated from a copper crucible under a pressure of $6.7 \cdot 10^{-3}$ Pa by means of two 50 kW electron guns. The initial temperature of the steel tape was varied from 190 to 210° C, its velocity was varied from 0.75 to 2 m/min, and its final maximum temperature was found to vary from 670 to 1010° C, depending on the other parameters. The plastic properties of the condensate were measured by the method of plane bending, according to the International Standard 1519-73, its film thickness was measured with an isotopic gauge, its strength was measured in a backward-and-forward bending test, and its microstructure was examined under an optical microscope. Profiles of the composition through film and substrate indicate that at temperatures above 800° C an iron-titanium alloy forms within the function zone, with the iron content increasing toward the substrate and the plasticity of the condensate decreasing as a result. The porosity decreases with increasing film thickness and with higher condensation temperature, but never below a residual 1 cm^{-2}, even in 17-μm-thick specimens. Figures 2; references 3: all Russian.
[169-2415]

UDC 620.194

SUBCRITICAL CRACK GROWTH IN TITANIUM ALLOYS IN AIR

Moscow ZASHCHITA METALLOV in Russian Vol 16, No 1, Jan 80 pp 14-20
manuscript received 1 Aug 78

MARICHEV, V. A., ROZENFEL'D, I. L. and LUNIN, V. V., Institute of Physical Chemistry, USSR Academy of Sciences

[Abstract] The relationship of crack growth rate to the coefficient of stress intensity K_I in air with normal humidity, in air dried with silica gel and in distilled water at 23° C was studied using titanium alloys VT5, VT4, VT3-1 and VT20. The basic mechanism of slow failure is hydrogen embrittlement. Crack growth stems from a combination of critical hydrogen concentration and triaxial tensile stresses. Subcritical crack growth and its impediment upon lowering K_I was manifested by diffusion of hydrogen to those sections of metal with maximum values of triaxial stresses. A model was proposed which makes it possible to determine the relationship of crack impediment time to the magnitude of K_I lowering and to calculate the effective values of the hydrogen diffusion coefficient in the plastically deformed zone near the crack apex. Figures 4; references 27: 7 Russian, 20 Western.
[86-6368]

UDC 621.9.047.7

INVESTIGATING ANODE DISSOLUTION OF TITANIUM ALLOYS IN SALT SOLUTIONS

Kishinev ELEKTRONNAYA OBRABOTKA MATERIALOV in Russian No 6, 1979 pp 12-15

DAVYDOV, A. D., KIRIYAK, Ye. N., KASHCHEYEV, V. D., KABANOV, B. N., Moscow

[Abstract] A study was made of the high rate of anode dissolution of titanium alloys containing various amounts of aluminum, molybdenum, and niobium as metals which have a lesser or greater tendency toward passivation than titanium. The alloys were prepared from metal powders in an electric-arc furnace in a helium atmosphere. Galvanodynamic polarization curves were taken at a rate of current variation of 0.033 amperes per second by linear law on a disk electrode rotating at a speed of 4,900 rpm. The current output was determined by the weight method on disk electrodes rotating at the same speed in the galvanostatic mode. The activation potential and the activated alloy dissolution potential in NaCl, $NaNO_3$, KOH and KBr solutions and mixtures of these compounds were studied. The current output for the dissolution process of all the investigated titanium alloys was highest in mixed chloride-nitrate solutions and lowest in potassium bromide solutions. Figures 4; references 14: 12 Russian, 2 Western.
[89-6521]

UDC 669.295

STUDY OF THE BEHAVIOR OF THE CONDENSATE DURING PRODUCTION OF TITANIUM BY THE MAGNESIUM-THERMAL PROCESS

Ordzhonikidze IVUZ, TSVETNAYA METALLURGIYA in Russian No 3, May-Jun 80 pp 65-68 manuscript received 9 Jul 79

TITARENKO, A. I., ALEKSANDROVSKIY, S. V. and ZAKHAREVICH, A. A., Chair of Light Metals and Rare Metals Metallurgy, Leningrad Institute of Mining, Leningrad; Titanium-Magnesium Combine, Berezina

[Abstract] A study was made of reverse 30% Mg + 70% $MgCl_2$ condensate with subsequent reduction in the magnesium-thermal process of titanium sponge production, to determine the dependence of its moistening rate on the ambient air temperature and relative as well as absolute humidity. Relative humidity was varied over the 15-92% range by adding saturated solutions of various salts. According to the experimental data, the moistening rate increases rapidly with decreasing absolute humidity and decreases sharply as the relative humidity drops below 45%. The moistening rate also decreases by almost 50% as the condensate is heated from 20 to 40° C and then remains almost constant till 80° C, becoming approximately equal to the dehydration rate of magnesium chloride. Tests with heavy-hydrogen water established that the oxygen-18 contamination is minimum in the $MgCl_2$ condensate dried at 185° C in an argon atmosphere and is minimum in the Mg condensate dried under vacuum. The optimum conditions for producing pure titanium sponge are vacuum drying at 185° C with the $MgCl_2$ condensate decanted during reduction of $TiCl_4$. Figures 2; references 2: both Russian.
[170-2415]

UDC 620.172

DEPENDENCE OF THE STRENGTH AND THE PLASTICITY OF TITANIUM ALLOYS ON THE DEFORMATION RATE

Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 80 pp 47-49 manuscript received 14 Jun 79

STEPANOV, G. V., Kiev, KOVALEV, B. A., Perm Institute of Problems of Strength, UkrSSR Academy of Sciences

[Abstract] An experimental study was made of the OT4 titanium alloy (as delivered) and of the VT3-1 and VT14 alloys (hardened by heat treatment) to determine the dependence of their mechanical characteristics on the deformation rate. Rod specimens 10 mm long and 4 mm in diameter were tested in tension at 20° C with an "Instron" machine, statically with

the deformation rate ranging from 10^{-3} to 10^{-1} sec^{-1} and dynamically with the deformation rate ranging from $6 \cdot 10^2$ to $20 \cdot 10^2$ sec^{-1} (corresponding to impact velocities from 6 to 20 m/sec). With increasing deformation rate, according to the test results, the strength of all these materials increases and their plasticity in terms of percent area reduction in necking remains undiminished. The relation between resistance to deformation and deformation rate becomes linear within the 10^2-10^3 sec^{-1} range, where a transition to the viscous mechanism of retarding glissile dislocations occurs. Figures 3; references 4: all Russian.
[171-2415]

UDC 669.691.2:542.943

CONCERNING THE KINETICS OF INTERACTION OF TITANIUM WITH OXYGEN AT REDUCED PRESSURE

Ordzhonikidze IVUZ. TSVETNAYA METALLURGIYA in Russian No 2, 1980
pp 62-66 manuscript received 30 Oct 78

PESHKOV, V. V., PODOPRIKHIN, M. N., VORONTSOV, Ye. S. and SPICHKIN, Yu. V., Voronezh Polytechnical Institute. Department of Welding Production Equipment and Technology

[Abstract] When solid polycrystalline titanium and its alloys are reacted with oxygen at high temperatures, there occurs both the formation and growth of an oxide film and considerable dissolution of the oxidant gas in the metallic base. The results are given of an investigation of the oxidation of grade VT1-0 titanium at a reduced air pressure of 10^{-1} mm Hg over the temperature range of 500 to 900° C, for the purpose of obtaining information on the kinetics and mechanism of the above-named reaction and isolating the influence of the two competing processes. Specimens measuring 16 mm in diameter and 2 mm thick were ground, polished and degreased and were oxidized in a furnace with a viewing window, making it possible to continuously observe the change in the interference coloration of oxide films and to compare this with the colors of reference specimens. The negative pressure was held constant by means of a fore-vacuum pump and a needle valve, and the temperature of the specimens was measured with a Chromel-Alumel thermocouple. The kinetics of the initial stages of oxidation were studied by measuring the time for a change in coloration of specimens over the color range of the reference specimens at different temperatures of isothermal oxidation and the thickness of the oxide film was determined by the ellipsometric method. With an increase in the thickness of the oxide film above a few thousand angstroms it was necessary to study the reaction by weighing specimens before and after oxidation, inasmuch as with these thicknesses the film becomes non-transparent to visible light. Results obtained from the interference indication method show that the time required for the formation of oxide films with the

reference coloration is reduced with an increase in oxidation temperature up to 625° C, and becomes longer above 625° C. Above 625° C the rate of dissolution of oxygen in the base increases to the extent that this dissolution considerably retards the growth of the oxide film. Up to 625° C the process of dissolution does not exert an important influence on the kinetics of oxidation of the metal. Curves derived from ellipsometric measurements show the dependence of the thickness of the oxide film on the temperature for various reaction times. With a constant oxidation time, the temperature dependence of the growth of the oxide film is not an exponential relationship, indicating the absorption of oxygen in the bulk of specimens. The results of gravimetric measurements indicate that in the range of 700 to 900° C oxidation takes place according to a law close to parabolic. It was found that the effective activation energy for the process of growth of oxide films increases from 22 to 48 kcal/mole with an increase in their thickness. Up to 625° C, with the presence of thin interference-colored oxide films on the surface of the metal, the electric field plays an important role, lowering the activation energy for the process. The results make it possible to suggest that with a temperature higher than 625° C an important role is played by the dissolution of oxygen, i.e., of the oxide film, in the metal base, evidenced in considerable inhibition of the growth of oxide films. Figures 3; references 7: 5 Russian, 2 Western.
[162-8831]

UDC 539.382:537.311.1

MEASURING THE DYNAMIC STRESS-STRAIN DIAGRAMS FOR TITANIUM AND COPPER UNDER DETONATING TENSILE LOADS BY THE ELECTRON-INERTIA METHOD

Kiev PROBLEMY PROCHNOSTI in Russian No 1, Jan 80 pp 75-77 manuscript received 18 Apr 78

KASHAYEV, Yu. G., NOVIKOV, S. A. and SINITSYN, V. A., Central Scientific Research Institute of Aircraft Engine Construction imeni P. I. Baranov

[Abstract] Rod specimens of VT14 titanium alloy and grade M1 copper were tested dynamically in tension, at deformation rates of $4 \cdot 10^2$ and 10^2 s^{-1} respectively. Pulse loads in the form of shock waves were produced by a detonating device and measurements were made by the electron-inertia method, using current transformers with 79NM Permalloy cores as transducers. This method of measurement is based on the proportionality of stress, strain, and voltage to the integral of current with respect to time. The error of these measurements was estimated by checking them against stress-strain diagrams independently obtained with tensoresistor gauges. In the case of the titanium alloy the discrepancy was found to be 4% for the dynamic yield point and 20% for the modulus of elasticity. In the case of copper the discrepancy between static and dynamic stress-strain diagrams did not exceed 3%. Figures 3; references 7: 5 Russian, 2 Western.
[123-2415]

UDC 669.715:621.77

ESTIMATING THE QUALITY OF A JOINT AND THE MAXIMUM PERMISSIBLE PRESSURE FOR CHANNELS BUILT INTO ROLLED-WELDED PANELS

Moscow TSVETNYYE METALLY in Russian No 6, Jun 80 pp 68-70

KORYAGIN, N. I., NESHPOR, G. S. and ANDREYEV, D. A.

[Abstract] Rolled-welded panels with aluminum channels are produced on a large scale, exceeding 7 million pieces annually, for use as heat exchangers in refrigeration and cryogenic equipment. Their performance under internal pressures up to 10 MPa in these channels makes the quality of the welded joints particularly critical. Here a semiempirical procedure is described which combines data of tensile tests with calculations according to the theory of fracture mechanics. Results are shown pertaining to channels made of the AMg2 aluminum alloy. Hot rolling with subsequent annealing at 490° C for 1.5 hours yield a stronger joint than with annealing for 10 min only and a much stronger joint than without annealing. A formula relating the ultimate internal pressure to the stress concentration factor and the channel width is established which involves a simple proportionality. Figures 3; references 8: 7 Russian, 1 Western.
[169-2415]

UDC 621.791.4.011:539.378.3

INFLUENCE OF THE INITIAL STRUCTURE OF THE METAL AND THE PARAMETERS OF DIFFUSION WELDING ON THE QUALITY OF OT4 AND VT6 TITANIUM ALLOY WELDS

Moscow SVAROCHNOYE PROIZVODSTVO in Russian No 6(548), Jun 80 pp 30-32

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[Abstract] An investigation was made of the effect of diffusion welding parameters and initial metal structure on the deformation of elements and the strength characteristics of welds made with OT4 and VT6 titanium

alloys. Before welding, the specimens were washed successively in gasoline, acetone and alcohol. Welding was done on an installation with radiation heating and level loading in a vacuum of from $7 \cdot 10^{-5}$ to $2 \cdot 10^{-5}$ mm Hg. Deformation was measured directly during welding. Mechanical impact bending and tensile tests were done by standard methods. Studies were also done to determine the influence of structural inhomogeneity on welding and deformation. It was found that the initial structure of the alloys in large measure determines the deformation of welded components and the quality of welds. The way that temperature affects deformation of components and weld quality depends on the level of applied stresses. The best combination of mechanical characteristics and retention of initial structure is realized by welding alloys with initial uniaxial fine-grained structure at maximum temperatures up to the onset of polymorphic transformation. Figures 4; references 5: 3 Russian, 2 Western.
[166-6610]

UDC 621.791.01:548.5:620.192.47

KINETICS OF DIFFUSION INCREASE IN THE VOLUME OF GAS BUBBLES IN A MELT

Moscow SVAROCHNOYE PROIZVODSTVO in Russian No 5(547), May 80 pp 1-4

NIKIFOROV, G. D., doctor of technical sciences, RADCHENKO, S. V., engineer, and VINOGRADOV, V. S., candidate of technical sciences, Moscow Institute of Aviation Technology

[Abstract] The liberation of gas in molten metal in the form of bubbles takes place in two stages: formation of stable bubble nuclei; development of these nuclei as the gas dissolved in the molten metal diffuses into them. The development of stable bubble nuclei takes place as a result of the tendency of the system to reach equilibrium between the pressure of the dissolved gas in the bubble and its concentration in the molten metal. An analysis of this equilibrium in the aluminum-hydrogen system shows that the growth-controlling process is the rate of hydrogen diffusion from the melt into the bubble. Since mathematical analysis of the process of diffusion growth of bubbles with time involves certain difficulties, the authors developed an engineering method of calculating the kinetics of bubble growth due to the diffusion of gas dissolved in the molten metal. To simplify the calculation, the process was broken down into a number of elementary acts of diffusion, assuming constant volumes and surface areas of the bubble in these intervals, as well as constant pressures in the bubble and concentrations of dissolved gas in the melt. It was assumed that a certain amount of gas penetrates into the bubble in each of these elementary acts. This technique and the derived equations were verified for the case of hydrogen dissolved in aluminum [illegible] shown that the degree of degasification of the meta. due to passage [illegible] ogen

from the molten metal into bubbles may vary widely for the same concentration of hydrogen and initial bubble radius depending on the total volume of bubbles or the number of bubbles per 100 g of metal. Figures 3; references 2: both Russian.
[164-6610]

UDC 621.791.762.5:539.43:669.295

FATIGUE STRENGTH OF TITANIUM ALLOY AND NICKEL-BASE ALLOY WELDS MADE BY RESISTANCE FUSION BUTT WELDING

Moscow SVAROCHNOYE PROIZVODSTVO in Russian No 5(547), May 80 pp 11-13

KUDRYAVTSEV, I. V., doctor of technical sciences, SLEPAK, E. S., candidate of technical sciences and SAVVINA, N. M., candidate of technical sciences, Scientific Research Institute of Technology and Machine Building

[Abstract] Resistance fusion butt welding with preheating is used to make ring-shaped items from VZh98 and VZh101 nickel-based and VT5-1 and VT20 titanium alloys in strips with cross sections of up to 3500 mm^2. Individual welding defects show up in inspection; others are revealed by radiography. Since there are no effective nondestructive testing methods, quality control is usually done by sample tests on specimens cut from the finished rings. However, since the defects are randomly distributed in the joint, it is difficult to evaluate the quality of the total weld from impact test results on standard specimens, and tensile testing on small specimens. Besides, tests of welds show a considerable spread of impact strength indices on specimens without evident defects. Sometimes in fracture testing the specimens break in the zone of fine-grained austenite even in specimens with weld defects. In this paper the authors propose norms for evaluating the quality of welds in different materials by the method of testing full-scale samples with determination of the nature of change in breaking load. The mechanical properties of welds were evaluated by comparing with properties of the base metal. It was found that welds in nickel-base alloys made by resistance fusion butt welding with typical defects have fatigue strength close to that of the base metal. The breaks in titanium alloy welds showed brittle smooth sections that do not reduce the fatigue strength of the welds as compared with the base metal. It was found that the fatigue strength of welds in these metals combined with sample static bending tests of full-size specimens with a sharp notch may serve to evaluate the quality of welds. Figures 1.
[164-6610]

UDC 621.791.4:539.378.3

FEATURES OF MAKING TITANIUM LAMINAR STRUCTURAL ELEMENTS BY DIFFUSION WELDING

Moscow SVAROCHNOYE PROIZVODSTVO in Russian No 5(547), May 80 pp 17-19

PESHKOV, V. V., candidate of technical sciences, KUDASHOV, O. G., candidate of technical sciences, GRIGOR'YEVSKIY, V. I., candidate of technical sciences, and PODOPRIKHIN, M. N., engineer, Voronezh Polytechnical Institute

[Abstract] Experiments were done on the feasibility of welding structural elements from OT4 titanium alloy components of small cross section (0.8-4.0 mm). The studies involved determination of the way that weld quality is influenced by the technique used for preparing the surfaces for welding, choosing the diffusion welding regime and the method of quality control. It was found that the best pre-welding treatment for surfaces with oxides and gas-saturated layers is sandblasting with dry quartz sand, chemical etching in a preparation containing hydrochloric and nitric acids and sodium fluoride, followed by brushing with a molybdenum wire brush. Diffusion welding should be done in two stages: first at a specific pressure of 0.05 kgf/mm^2 and a temperature of 950° C for 20 minutes, and then at 0.1 kgf/mm^2 and 1000° C for 90 minutes. Quality control should include measurement of accumulated deformation. Figures 6; references 4: all Russian.
[164-6610]

UDC 621.794.052:539.4

INFLUENCE OF LOCAL HEAT TREATMENT WITH A PLASMA JET ON THE COLD-CRACKING TENDENCY OF HIGH-STRENGTH STEEL WELDS

Moscow SVAROCHNOYE PROIZVODSTVO in Russian No 5(547), May 80 pp 25-26

NIKITIN, V. M., candidate of technical sciences, REMIZOV, V. Ye., engineer, FEDOROV, V. G., candidate of technical sciences, and BULYGIN, A. G., engineer, Moscow Institute of Aviation Technology

[Abstract] Heat treatment of welds is one of the major ways of reducing cold-cracking of joints made by welding in high-strength steels. The authors studied the way that local heat treatment affects cold-cracking on annealed specimens of 25KhGSA, VP-25, KVK-32 and VKS-1 (42Kh2GSNM) steels 2-2.5 mm thick. All specimens were hard-surfaced by argon-arc welding in the center. Then a plasma jet with argon as the plasma-forming gas was used for local heat treatment. Local heat-treatment temperatures ranged from 220 to 780° C. Cold cracking was evaluated from the critical

pressure reached under loading on the LTP-2-5 testing machine. If the specimens withstood the maximum load of 150 kgf/cm^2 for 24 hours, the time was extended to 72 hours. On 25KhGSA steel after welding, cold cracking starts at 60 kgf/cm^2. Local heat treatment at 220° C raises the critical stress to 70 kgf/cm^2. Increasing the local heat treatment temperature to 680-700° C eliminates cold cracking even at the maximum load. Generalizing the results for all steels studied, it is found that the optimum heat treatment is somewhat below 680-700° C. Figures 1; references 8: all Russian.
[164-6610]

UDC 621.791.3.04

STRENGTH OF KhN60VT ALLOY JOINTS MADE BY HIGH-TEMPERATURE SOLDERS

Kiev AVTOMATICHESKAYA SVARKA in Russian No 5(326), May 80 pp 58-59, 63
manuscript received 21 May 79 after revision 6 Sep 79

KISELEV, O. S., GRUZDEV, B. L., candidates of technical sciences,
DUMANSKIY, V. G. and TSYBINA, L. S., engineers, Ufa Aviation Institute

[Abstract] Studies were made of the short-term and long-term strength of lapped joints of KhN60VT alloy plates 1.2 mm thick made with VPr7 and VPr8 high-temperature nickel-based solders. Soldering was done in an electric furnace at 1180-1200° C with holding for 10-15 minutes. Tests were done by a standard technique. It was found that lapped joints made with VPr7 alloy are nearly as good in all indices as those made with VPr8. While VPr8 solder contains tungsten and retains its mechanical properties better than VPr7 solder at high temperatures, its technological properties are inferior to those of VPr7, and other things being equal, VPr7 gives a joint of better quality. Given the close results of the tests, it is recommended that VPr7 alloy be substituted for VPr8. Figures 3; references 2: both Russian.

WAYS OF ECONOMIZING ON METALS

Novosibirsk EKONOMIKA I ORGANIZATSIYA PROMYSHLENNOGO PROIZVODSTVA
in Russian No 4, 1980 pp 124-135

[Article by Candidate of Technical Sciences A. F. Myrtsymov, Moscow]

[Text] A decree of the Central Committee of the CPSU and the Council of Ministers of the USSR, "Improvement of Planning and Intensification of the Action of the Mechanism of Economy on Production Efficiency and Work Quality" specifies a program for saving metal among the first-rank plans for the immediate future.

Serious problems due to a shortage of metals have arisen in many sectors of the national economy. There are many reasons for this: inefficient use of metal, high levels of wastes and losses, which are due in turn to a lack of high-quality forms of metal production, ineffective structure of technological modifications (low specific weight of electric steel production, continuous teeming of steel), lack of regulated rolling conditions, low level of automation of production processes and so on.

This is not the first time that our magazine has dealt with the problems of ferrous metallurgy. The outlook for development of this sector and its reserves has been discussed here by Academicians B. Ye. Paton and A. I. Tselikov, Doctor of Economic Sciences V. I. Cheplanov, Doctors of Technical Sciences A. A. Vertman and Ye. S. Kalinnikov, Candidate of Economic Sciences I. G. Pashko, Candidates of Technical Sciences A. N. Glazov, E. B. Golland and others (EKO, No 4, 1974; No 3, 1976; No 3, 1977; No 1, 1979).

In connection with the forthcoming development of a comprehensive scientific-technical and economic target program on saving metal, our magazine has felt that it might be useful once again to offer specialists an opportunity of analyzing the existing situation in this sector and giving their recommendations on ways to improve technology, production organization and economizing on ferrous metals.

Ferrous Metallurgy -- an Intensive Path to Development

Two ways

The Soviet Union has far outstripped all other nations in the volume of production of ferrous metals. Despite this, we still feel the shortage of rolled goods and pipe, and have been forced to increase the import of metal goods. It has become necessary to concentrate the development of ferrous metallurgy in such areas as would enable us to eliminate this shortage.

What are the possible ways of solving this problem?

We could of course in the future develop ferrous metallurgy along the path of a further increase in volumes of ore, coking coal, fluxes, coke, sinter cake and rolled briquettes, smelting of cast iron and steel, production of rolled goods and pipes and so on. For example some specialists have proposed that steel smelting be brought up to 250-300 million metric tons by the year 2000. Forecasts are being worked out, according to which there will be a continued appreciable increase in cast steel production up to the year 2000, even though production volume has now reached large proportions in our nation, completely unjustified from either the technical or economic standpoint. It is suggested that the output of cast iron will increase from 24 million metric tons in 1975 to 29-35 million metric tons in the year 2000, with a corresponding increase in cast steel from 5.6 to 8-10 million metric tons with a general volume of capital investments in developing new facilities for casting production alone (without even considering investments for increasing the capacities of coke production, iron smelting and so on) amounting to about 20 villion rubles for 1981-2000.

Unfortunately we have to note that under present conditions there will be no other way to ensure supplies of metal stock except by increasing casting production. We can get an idea of the low effectiveness of casting as compared to rolling from data obtained by I. G. Pashko. He has established that labor productivity in foundries is 12 times lower than in rolling mills, and that substituting rolled goods for one million metric tons of castings could save more than 375 million rubles on capital investments, and more than 140 million rubles on overhead expenses in a year.[1]

Extensive development of ferrous metallurgy while the quantitative growth in metal output outstrips qualitative growth will unavoidably lead to deterioration of the economic standing of the sector since poorer and poorer iron ore resources will be used with less and less iron content.

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[1]I. G. Pashko, "Problemy snizheniya metalloyemkosti" [Problems of Reducting Metal Inputs], Moscow, Metallurgiya, 1977, p 90.

Another way to develop ferrous metallurgy is to intensify it with a pronounced improvement in the quality and variety of metal goods.

In most cases the proportions of goods made from ferrous metals are not dictated by the service conditions of articles, machines, structural elements and the like. For example the specific expenditure of metal for a gas line can be cut approximately in half if pipe diameter is increased from 1020 to 1620 mm with a simultaneous increase in the strength of the metal from 52 to 80 kg/mm^2. The use of tubular supports in place of conventional pilings practically cuts metal inputs in half. Rolling wide-flange girders and channel beams on a continuous mill brings about conditions for producing structural shapes with wall thickness 1.5-2 times less than on a conventional universal mill.

We could go on giving examples like this. They all have the same message: the requirements of the metal-utilizing sectors of the national economy should not be measured in metric tons of metal, but rather in square meters of flat rolled stock, running meters of structural shapes and pipe with well-defined and regulated service characteristics specified by the user. In this way the weight of any machine, structure or installation can be considerably reduced.

This will considerably reduce the total requirements for metal, the specific expenditures of fuel and energy, increase the useful load-bearing capacity of many machines, and so on.

Can metallurgists appreciably improve the quality of metal? After all, increasing the output of low-alloy steels (and in this area we are way ahead of all other countries) will have no noticeable effect without conventional or mechanical heat treatment of the rolled goods made from such steels. But we feel that metallurgists can considerably improve metal quality. In recent years a number of metallurgical processes have been developed that can be applied to low-alloy and micro-alloy steels, and in certain cases even to simple carbon steels, to give them properties that in the past could not be achieved even by heat treatment of alloy and low-alloy steels. For instance by using a monitored schedule for production of metal goods throughout the entire cycle of preparation, rolled stock can be made with a guaranteed yield stress of at least 50-60 kg/mm^2 and with characteristics that are superior to those of the ordinary metal with respect to ductility and impact strength, including at arctic temperatures[1], weldability, and other important service characteristics; research has confirmed the feasibility of producing rolled stock with a strength of 130-140 kg/mm^2. Continuous annealing on a special schedule even on low-carbon metal in a thin strip (frequently in combination with the use of special treatment schedules in a metal-working enterprise) also now opens up extensive possibilities for achieving quite high mechanical and technological properties of rolled stock.

[1]"Chemical Economy and Engineering Review," Vol 11, No 1-2 (124), 1979, pp 57-58.

And what is more important, the attained results are far from the limit. For example a reduction in the grain size of metal will bring the actual mechanical properties much closer to the theoretically attainable level.

A monitored schedule for production of metal goods usually includes: desulfurizing the low residual concentrations of sulfur from cast iron outside of the blast furnace, and in isolated cases additional treatment of the steel with rare-earth and certain other additives outside the furnace; refining the steel outside of the furnace; continuous teeming of metal; monitored rolling, including at low temperatures; annealing of cold-rolled low-carbon steel band; appropriate testing of the finished goods. It is evident even from this brief list that when obsolescent and technically inadequate metallurgical equipment is used, this type of monitored schedule for metal production cannot be carried out. It requires highly rigid mills and high-power motors, the appropriate lines are needed for continuous annealing, and so on. Consequently the organization of mass production of rolled stock and pipes that have properties much superior than nowadays will require a radical change in processes, and extensive retooling of metallurgical plants. But in compensation, opting for this direction guarantees much better satisfaction of the growing needs of the national economy for ferrous metals with much lower volumes of production.

Another area that is just as important is the range of goods, the structure of production and the demand for ferrous metals. We mentioned above the incomparably large scales of iron production, and particularly of cast steel production in our nation. For example in Japan the volume of cast steel with respect to the amount of rolled stock has fallen on the average to 0.8% for 1973-1976 as compared with 1.65% for 1960-1964, while the corresponding figures for cast iron were 5.6% as compared with 11.9%. The ratio for West Germany over the same period decreased from 1.36 to 0.93% for cast steel, and from 14.8 to 11% for cast iron; for Belgium from 1.05 to 0.35% and from 6.0 to 2.4% respectively, and so on.

Another fundamental characteristic of the range of metal goods from the standpoint of its effectiveness is the ratio between the production of rolled sheet and structural steel. Soviet ferrous metallurgy is characterized by a much lower specific weight of flat rolled goods than other industrialized nations: for us this fraction does not exceed about 40% in recent years as compared with 60-65% for most industrialized nations. Things are even worse when it comes to cold-rolled steel sheet and band: the proportion of these goods in the general output of rolled stock in our nation is approximately 3.5 times lower than in the United States. And it is in the use of flat rolled stock, and especially cold-rolled goods, that the metalworking industry can realize the most significant reduction in inputs of metal and labor.

On the basis of these remarks, we can formulate the major directions that would enable us to achieve a radical improvement of production efficiency and utilization of metal over the next two decades.

Production volumes

Since it is rolled goods rather than steel that is needed by the national economy, it seems to me that the deciding index of the level of production of ferrous metals should be the output of finished rolled goods. Calculations show that a radical change in the quality and specifications of technological processes can considerably reduce the increase in volume and satisfy the needs of the national economy.

If in future we can learn to produce two-thirds of the rolled stock by monitored methods, attain a specific weight of sheet of 65-70% (with large-scale use of protective coatings), including 30-35% cold-rolled sheet, and an average level of yield stress of at least 55-60 kg/mm^2, we will be able to reduce the overall production of metal by a minimum of 20 percent.

Metallurgical production processes

It was in our nation that the process of continuous teeming of steel was first developed and introduced. However, in recent years we have been seriously falling behind in this area. For example in 1977 the proportion of this progressive process in the overall production of steel in Japan was greater than 40%, and in a number of countries (including West Germany, Italy, Austria and Sweden) it was in the neighborhood of 30-40%, while in the Soviet Union it was even less than 10%.

And by this process alone we could increase the yield of usable rolled goods from molten steel by 10-15%, and consequently considerably reduce the melting of steel and iron, production of coke and sinter cake, extraction of ore and coal and so on. Moreover, as has now been established, there is no way to achieve a successful solution of many problems of radically improving the quality of metal goods in general without using continuous teeming of steel, and this applies in particular to conditions of producing rolled stock in a monitored schedule.

From the technological standpoint, continuous teeming can feasibly be used for nearly all flat rolled stock, blanks for making seamless tubing (including centrifugal casting), and a quite considerable portion of the metal intended for making structural rolled steel. It is not clear as yet whether this process could be used for casting bearing steels, although published data indicate that even in this case the use of continuous teeming improves metal quality, including with respect to such an index as the nature of contamination with nonmetallic inclusions. Apparently it has not been possible to cast high-alloy steels and other alloys by the continuous method; however, the scales of production of such metals are relatively low. It can be expected that by the year 2000 about 80-90% of all melted steel could and should be cast by the continuous method. Since the use of continuous teeming on a large scale increases the yield of usable rolled goods by 10-15% as compared with ingot casting,

and it is our opinion that no more than 1-1.5% of the melted steel will have to go for production of cast structural shapes, it can be assumed that melting of steel will surpass the output of rolled goods by a factor of about 1.1.

In view of the need for producing high-quality rolled stock and extensive use of continuous teeming of steel, we need extensive introduction of "ladle metallurgy," i. e. the use of treatment of the molten steel out of the furnace by evacuation, treatment with slag and so on. Since similar types of treatment will be needed on nearly all the metal going to facilities for continuous casting, as well as on all stainless steel and some other grades of metal with especially low carbon content, even if they are not going on to continuous teeming, it can be assumed that by the year 2000 "ladle metallurgy" will include at least 80-95% of all steel melting.

Metal of the quality being discussed here cannot be melted in open-hearth or two-bath furnaces, nor is this advisable. Therefore it will be necessary to use only the oxygen-converter method and electric melting to produce the steel, and by the end of the given period, the most probable ratio between these methods will be about 2:1.

In recent years considerable advances have been made in metallizing iron ore materials. For instance there has been a considerable increase in the productivity of a unit facility (module): very recently it was 400,000 metric tons per year, it is now approaching 800,000 metric tons per year, and modules are being designed for 1-1.2 million metric tons of metallized intermediate material per year. Energy expenditures have been reduced somewhat; briquetting of fines is being introduced, which is increasing the yield of usable material; passivation (coating with an oxide film) has been mastered, enabling transportation of metallized materials to great distances over land and sea, and so on. It can be assumed that by the end of the century the production of metallized materials in our nation could be at least 15-20% of steel production, volumes of iron smelting could be considerably reduced even below the present level, and consequently it would be unnecessary to build new blast furnaces, coke batteries and sinter caking mills.

In the forthcoming decades the production of articles by ceramal methods will receive considerable development. This means that metallurgists will have to organize large-scale production of the required powders. In ferrous metallurgy itself, processes will come into industrial use in which blanks for rolling and forging are made by pressing a melt granulated in a neutral medium. This technique will evidently be most advisable in the production of high-speed steels, high-temperature alloys and other heavily doped alloys.

Such development of ferrous metallurgy requires decisive reconstruction of metallurgical machine building, an increase in working capital, and a change in nomenclature of equipment produced.

Miniplants and service centers

The problems of developing miniplants have been discussed in some detail in this magazine.[3] There may be arguments about specific layouts, but one thing is clear: the production of rolled structural shapes and different sizes of section iron can be expanded only by combining the work of large integrated plants and miniplants, where the former mass-produce rolled goods, while the latter meet the specific needs of local customers.

The development of service centers does not directly involve problems of development of ferrous metal production, but is closely related for two reasons. First of all such centers considerably facilitate the operation of large modern ferrous metallurgy plants, enabling them to produce rolled goods in large batches. At the same time, they provide customers with metal goods in the forms and amounts necessary for each of them. In the second place, a well organized and properly operating system of service centers where a variety of procurement operations in metalworking production can be done enables a savings of at least 10-15% of the metal as compared with the case where each metalworking enterprise must carry out all its own operations on dressing and preparing the metal. At the same time, conditions are brought about so that hundreds of thousands of customers for metal goods are freed from the necessity of setting up small, often inadequately mechanized and low-productivity procurement shops, and in many cases the need for setting up intermediate metal warehouses is completely eliminated. All this will free considerable material and labor resources that are now being ineffectively used in procurement production by many metalworking enterprises.

Additional efficiency factors

Calculations of the options of intensive and extensive development done by the the Institute of Economics and Organization of Industrial Production of the Siberian Department of the Academy of Sciences of the USSR show that in the former case the requirement for capital investments is much lower. In this connection, consideration should be taken of the savings that could be realized by a reduction of investments in the casting industry, extraction of coking coal, transportation of surplus cargo and the like. But no matter how important such a large savings is in itself, we believe that the intensive option provides a number of other effects as well.

Labor resources cannot keep up with retention of the traditional method of developing ferrous metallurgy with gradual improvement of technology. Even now, the employment in the sector is such that the annual steel

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[3]E. B. Golland, "Ferrous Metallurgy of Today and Tomorrow," EKO, No 4, 1974; A. A. Vertman, A. N. Glazov, Ye. S. Kalinnikov, "Promising Outlook for Miniplants," EKO, No 4, 1974; A. F. Myrtsymov, "Miniplants and Ferrous Metallurgy," EKO, No 7, 1979.

melting per worker is 120-130 metric tons. Even in our large plants this figure does not exceed 350-400 metric tons. At the same time, enterprises equipped with modern facilities are operating in industrialized nations at a steel melting level of more than 1000 metric tons per year per worker -- and such figures are realized not only in large enterprises, but in miniplants as well. Obviously a further increase of employment in the sector is quite problematical.

A reduction in the volume of metal that is handled will enable sectors that use rolled goods to reduce expenditures of capital investments and overhead associated with working the material (machine tools), storage, warehousing and transport.

Improvement of quality brings about potential capabilities for improving reliability and durability of machines, which in turn will reduce outlays in sectors that use the output of machine building.

Some organizational questions and problems of management

It is completely obvious that ferrous metallurgy is in no position to resolve independently all the problems involving a radical change in production and use of metals. Therefore a comprehensive target program on saving metal should provide for solving the following problems.

- Reorientation of metallurgical machine building toward production of up-to-date equipment for metallurgical plants. A concomitant intensification of investments in development of this sub-branch. According to the results of research by a number of organizations, major production funds in metallurgical machine building should be at least doubled with simultaneous replenishment.

- Expansion of the specialized construction base, and orientation of this base toward accelerated construction and modernization of metallurgical enterprises. At the same time, there should be an improvement in the planning system with provision for using not only progressive equipment and technological processes, but also modern construction modules, a reduction in the underground part of structures, surface installation of ductwork, and an overall reduction in the physical volume of structures.

- Experience of the last decade shows that despite a considerable increase in the production of high-quality rolled goods, the coefficient of utilization of metal in machine building is changing slowly, and comes to about 0.72-0.725. Consequently the target program should include correction of all design and technological documentation, a re-examination of production technology from the standpoint of predominant growth of metalworking by methods of plastic deformation, casting shrinkage and machining, the use of other modern technological processes, and also a progressive change in the normatives of metal expenditure in all metal-using sectors, setting up and rigidly controlling the normatives of casting expenditures.

• Evaluation of work results in ferrous metallurgy based on criteria established in the July 1979 decree of the Central Committee of the CPSU and the Council of Ministers of the USSR in accordance with which the enterprises of the sector are oriented primarily toward the consumer qualities of the metal that determine the effect for the user.

[154-6610]

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CSO: 1842

METALS CAPACITY: TECHNOLOGY AND ECONOMICS

Novosibirsk EKONOMIKA I ORGANIZATSIYA PROMYSHLENNOGO PROIZVODSTVA
in Russian No 4, 1980 pp 136-145

[Article by L. L. Zusman, doctor of economic sciences, professor]

[Text] The level of utilization of metal in metalworking and machine building; the mass of metal in machines and equipment with respect to their working parameters; the expenditure of spare parts over the service life of the machine -- these three indices characterize the technological, functional and operational input of metals respectively. These indices must be considered in the aggregate when studying the general problem of metal inputs in social production. Otherwise it may not be noticed that a savings of metal in one of the links of this chain brings about additional expenditures of metal in another link.

Unfortunately, many specialists consider the problem of metal inputs in social production mainly from the standpoint of the organizational and technical measures that must be carried out in ferrous metallurgy or in the metal-using sectors, but in doing so they miss some of the economic and socio-organizational aspects of the problem, and unless these are taken care of the recommended measures are implemented extremely slowly or else left unrealized.

The decree of the Central Committee of the CPSU and the USSR Council of Ministers "Improvement of Planning and Intensification of the Action of the Mechanism of Economy on Production Efficiency and Work Quality" aims at improving the former resolution of problems that arise. In our opinion, the following measures are desirable for realizing the principles of this decree.

The results of economic activity of metallurgical enterprises should be evaluated not only on the basis of the newly created value (net production), but also on the basis of labor inputs for delivered types and sizes of goods (standard tonnage). We prefer the "standard tonnage" index since it is more accessible to the understanding of each worker in rolling production, is applicable to the output of any rolling mill,

is more easily taken into account over any period (including by the shift, by the day, and by the ten-day period), and therefore enables dynamic control of the quality and variety of output.

The proposed order of evaluating the economic activity of metallurgical enterprises agrees completely with the conventional accounting of the output of metallurgical goods in physical tonnage. With the aid of this index one can determine the balance of ferrous metals and the increment in volume of output over a planned period as against a basis period. But the planned percentage increment as calculated from physical tonnage should correspond to the increment in output as calculated in terms of standard tonnage.

The system for accumulating incentive funds should be based on the index of quota fulfillment in terms of net production or in standard tonnage. The same applies to the results of socialist competition both within enterprises and between them. Accounting for the output of rolled goods in standard tonnage is possible only when a coefficient of labor intensiveness has been worked out and approved with respect to each position in the production of rolled goods, and with respect to each rolling mill -- coefficients that are periodically re-examined when production conditions change.

Since early 1978 the work of production enterprises has been evaluated from the volume of sales of goods with consideration of satisfaction of customer orders. But this has not solved the problem of meeting the requirements of the national economy for the required variety of goods, since conditions of scarcity of metals force the customers to conform to the demands of the supplier under the threat of not being able to realize the funds allocated. A radical way out of this situation would be to eliminate the tension in Soviet-wide annual plan balances of production and utilization of metal in range of variety, in creating reserves, and in changing to wholesale trade in the means of production, which includes ferrous metals.

The machine builders are in a position of offense relative to the metallurgists, rightfully pointing out the inadequacies in quality and variety of metal goods. But at the same time, they rarely mention eliminating the excess consumption of metals in machine building. In the best case it is pointed out that there is a need to reduce the metal wastes that result when machines and equipment are being made. Actually, the accountable metal wastage in machining and machine building has increased on the average from 200.6 kg/metric ton in 1965 to 202.2 kg/metric ton in 1977. With respect to iron and steel casting, which is done mainly by the machine building enterprises themselves, the overall losses of metal surpass 2 million tons per year, including more than 1.7 million metric tons of shavings removed each year in cleaning up castings. In addition, consideration must be taken of the fact that removing chips involves considerable production outlays: according to the results of a

special study, these outlays have averaged about 500 rubles per metric ton of chips, and consequently have come to a total of about 850 million rubles. And according to data of the Institute of the National Economy imeni G. V. Plekhanov,[1] the specific capital investments per metric ton of shavings reach 1,085 rubles.

The major reason for such metal losses and production outlays in cleaning up castings is that the ingots are made with large machining allowances because foundry practice has been slow to introduce modern automatic molding lines and mixtures that harden directly in the mold. This in turn can be attributed to the considerable decentralization of foundries and casting sections, most of which are poorly equipped. The persistence of these facilities that produce castings with wide machining allowances and high production costs reflects the propensity of machine building and other enterprises to have their own foundry base. After all the foundry industry is not institutionally funded like rolling production, and casting can be based on internal resources (metal wastes). Let us add that the Central Statistical Administration of the USSR keeps track only of the rolled goods used in machine production, and any part of the rolled stock that is replaced by castings drops out of the statistical account.

Replacing rolled goods with castings that do not have high strength, as a rule, increases the weight of machines and equipment. But in cases where output has been accounted for in terms of mass (e. g. metallurgical and petroleum equipment), the excess weight has been transformed into a boon for the enterprise, since it has helped to overfulfill the quota for gross production, winning prizes. In accounting for fulfillment of the production quota for other kinds of machines and equipment by the piece or in terms of value, their mass is not taken into consideration, and does not serve as an index for evaluating the activity of the enterprise. On the other hand, wholesale prices, as a rule, take consideration of the actual mass of the various kinds and models of machines and equipment.

The planning of machine building output in a certain product list as provided for by the decree of the Central Committee of the CPSU and the USSR Council of Ministers on improving the economic mechanism, should be accompanied by planning of their mass with respect to the major points of this product list based on progressive normatives, with corresponding planning of material and technical supply, and in the evaluation of production activity as well as in the indices of socialist competition, consideration should be taken of lightening of the mass of machines and equipment with respect to their technical parameters.

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[1]N. P. Ivantsova, "Nauchno-tekhnicheskiy progress i struktury metalopotrebleniya" [Scientific and Technical Progress and Structures of Metal Utilization], Moscow, Nauka, 1977.

It is further advisable to accelerate the mass replacement of cupola furnaces with electric furnaces for melting high-strength cast iron. This will lighten components by 15-20%, concentrate the production of cast iron and steel, eliminate the multitude of small foundries, facilitating the corresponding cooperation in supplying castings. Automatic molding lines and cores that harden in the mold should be more extensively used in the remaining foundries.

Outlays for cleaning up castings in the procurement shops of the metalworking, machine building and other sectors are estimated in a range of 4.0-4.3 billion rubles per year, and adjusted expenditures with consideration of capital investments surpass 5 billion rubles.

Studies of heavy and transport machine building enterprises show that the way ferrous metals are worked is usually selected not on the basis of the optimum choice of method (casting, forging or machining), and not on the basis of economizing on metal or running expenditures, but rather from considerations of available facilities that are free at the given moment. And since the range of machines being produced frequently changes, there is also a change in the availability of free facilities in a given branch. Because of this, additional hundreds of thousands of metric tons of metal are wasted, and additional hundreds of millions of rubles of running expenditures are wasted on working the metal. To have the capacities for working the metal by optimum methods, free facilities of procurement shops are needed in the metallurgical enterprises, and it would be still better to concentrate metalworking and the production of finished pieces in specialized intersectoral casting, forging and metalworking enterprises based on cooperation with machine building enterprises. Resolution of this problem presupposes intensification of standardization in machine building, and clear organization of intersector and intrasectoral cooperation, and the availability of insured reserves of finished components in machine building enterprises.

About 20-25% of the metal resources are expended for spare parts because of the poor durability of components and elements of machines and equipment, their low reliability and short service life, and carelessness in utilization.

At the present time, the concern of the machine building enterprise ends with the sale of machines. In some cases during the warranty period worn out machine components and elements are replaced free of charge, but upon the expiration of this period the machine building enterprise bears no obligations whatsoever. Since the warranty period makes up about 10-15% of the entire service life of machines and equipment, the machine building enterprise bears very little material responsibility for reliability and durability of the machines and equipment it produces. This responsibility could be increased by obliging the machine building enterprise to repair and supply spare parts for the machines it delivers throughout the entire service life of the equipment. To do this, the machine

building enterprise would have to have the corresponding supplies of replacement components and elements for past and current models of machines, as well as a staff of repair personnel (with a corresponding reduction in other sectors). The result would be not only a considerable reduction in cost of the spare parts produced, and in the expenditures of metal for these needs, but also a study of the flaws detected during operation of the machines delivered, and elimination of these defects in later models of machines and equipment. Naturally penalty sanctions will be applied in cases where the components and elements of machines fail due to violation of the rules of operation and upkeep.

N. N. Smelyakov points out that "the specific metal inputs in Soviet machine building are one-quarter higher than in many other industrialized nations."[2] Naturally this does not apply to all kinds of machines. Many machines are now in use that are highly praised for their design characteristics, including weight characteristics. However, a great deal of Soviet machinery and equipment has a high specific metal input. Significant reserves for reducing the specific mass of machines are to be found in improving methods of designing the components and elements of machines and equipment. Existing methods and means of design to a considerable extent are antiquated and do not come up to the current scientific level of knowledge in the area of strength of materials. No calculations are done at all for the cross sections of most of the supports for metal cutting machine tools, forging and pressing machines, rolling mills and the like. The cross section of these metal-consuming elements is decided from so-called "design considerations." In selecting the cross sections of other elements of machines, safety factors as high as five or even sometimes ten are used. These safety factors reflect old practices due to actual lack of knowledge of the properties of materials, and unreliable calculations of the stresses in structural components during work. However, under present conditions with the use of high-speed computers, we can determine the exact pattern of stress distribution in the components of structures, and can select the optimum shape of these elements with elimination of redundant safety factors.

We feel that the time has come to work out and publish obligatory unified handbooks for strength calculations, doing away with departmental methods of calculation and sectoral norms. It would be useful to institute a systematic check on the use of up-to-date methods of calculating metal structures in planning and design organizations. We should also organize a number of interdepartmental laboratories on strength-testing metals to provide conclusions about the conformity of production calculations to the results of full-scale tests, and publish GOST State Standards to establish the proper order for carrying out and checking calculations for mass-produced items.

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[2]N. N. Smelyakov, "S chego nachinayetsya Rodina" [How does the Fatherland Begin], Moscow, Politizdat, 1975, p 224.

The system of awards to workers in design and planning organizations should also be directed toward economic stimulation of using progressive methods of calculations that reduce the metal inputs of items being designed without reducing their durability and reliability.

For a long time, design calculations have used a correction factor of 0.85-0.90 for the calculated cross section to ensure strength of structures due to nonuniformity of the properties of a given grade of steel. Use of this correction factor increases the weight of machines and structural elements by 11.1-17.6%, which amounts to about 8-12 million metric tons per year. At the same time, mass observations have shown that it is only less than 2-3% of the rolled goods made from carbon steel that has strength properties corresponding to the limiting value specified by the GOST specifications, while the other 97-98% actually has even higher strength.[3] Because of inadequate differentiation of strength properties within the range of a given grade of carbon steel, and corresponding differentiation of warehouse prices, metallurgical enterprises do not have the economic stimulus for improving strength characteristics. Due to poor input control, machine builders do not get information on the actual level of strength of the metal they receive, and designers increase the calculated cross sections of structural elements "to cover all bases." This extends the excess consumption of millions of tons of metal per year, not to speak of the enormous excess running expenditures for the entire service life of overweight transport and transporting facilities. And the transport facilities (rolling stock of the "Transport" sector, derricks and road construction equipment, roller conveyers and the like) contain about 20% of all the metal to be found in the fixed capital of the national economy.

Differentiation of indices in GOST State Standards for the strength properties within the limits of a given grade of carbon steel of ordinary quality and structural steel in correspondence with the differentiation of wholesale prices would reflect the economic interests of both metallurgists and metal users, and would be an important means of reducing the metal inputs in machines and equipment.

In considering the problem of economizing on ferrous metals, it is usually pointed out first of all that the quality and variety of ferrous metals must be increased. After that, the need for improving the design of machinery and equipment is indicated, and almost no mention is made of the problem of optimizing the range of machine models in accordance with the needs of the national economy. At the same time, herein lies the potential for a great savings of metal. This is evidenced by the example of production of metal cutting machine tools.

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[3]For more detail on this point, see the article by L. L. Zusman and N. K. Galayda, "Reserve for Saving Ferrous Metals" in "EKO," 1979, No 1.

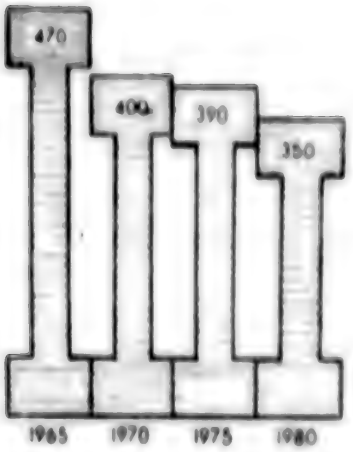
A comparison of analogous models of Soviet and non-Soviet machine tools shows that there is a difference in the structure of sizes and types: small metal-cutting machine tools costing less than $1000.00 apiece make up 73.4% of the total output in the United States, while in the Soviet Union analogous machine tools costing less than 750 rubles apiece make up only 21.8% of the total output; the other machine tools produced are of intermediate and high power. With increasing dimensions of machines, the expenditure of metal frequently rises in geometric proportion. For example, the strength and rigidity of a light machine tool can be adequately ensured by using welded structural elements of rolled sheet steel, but even moderately powerful machine tools usually require a cumbersome and heavy cast support. For this reason the average weight of a metal cutting machine tool in the Soviet Union is about 2.5 times as high as in the United States, resulting in consumption of an additional 300,000 or more metric tons of metal per year.

The sizes of machine tools do not always correspond to efficient use. About 30% of the workpieces machined on heavy lathes could have been turned on machines with half the swing, 42% needed half the distance between centers, and 28% even required only one-third this distance. In 70% of the operations carried out, less than half the capacity of machine tools is used with respect to the maximum mass of the workpieces being machined.

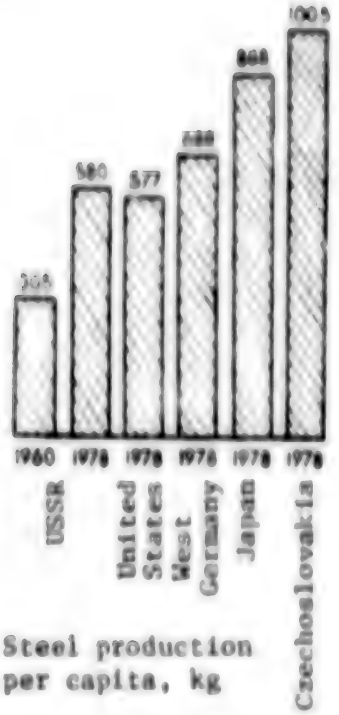
Apparently the main reason for excess output of more powerful metal cutting machine tools, hoisting cranes and the like is in the indices of fulfillment of quotas by machine builders with respect to gross production and sales, since under conditions of scarcity the customers will not refuse machines of higher unit power than they need. Apparently to eliminate this situation it is necessary to plan for machine building enterprises to produce machines by models in strict accord with the requirements of customers, and to disregard the production of machines in departure from the plan when determining quota fulfillment. The indices planned for machine building enterprises should also be made to agree with the confirmed plan in product mix and models.

New wholesale price lists for ferrous metals were put into effect on 1 January 1976. The prices and surcharges in these lists are more differentiated than in previous lists, which should be conducive to an improvement in the variety and quality of ferrous metals. Experience in using the new wholesale prices will show their advantages and disadvantages. Nevertheless, wholesale prices in a number of cases do not eliminate the contradictions between national economic interests and the interests of collectives of metallurgical enterprises.

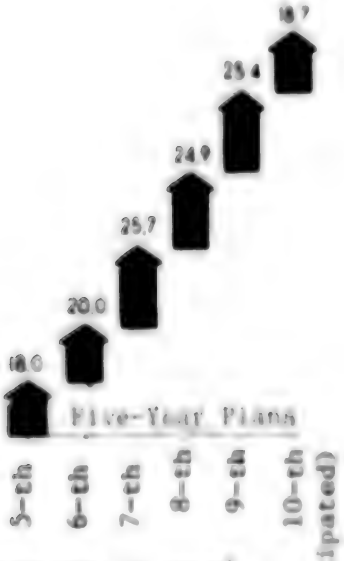
For example, the use of high-quality transformer steel reduces losses of electric energy. From the national economic standpoint this savings of electric power reduces capital investments in building electric power plants and facilities in the fuel industry. However, for those using



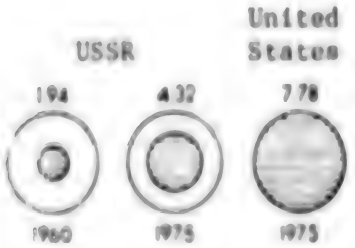
Metal input of the national income, kg of steel per million rubles



Steel production per capita, kg



Increase in steel production by five-year plans, millions of metric tons



Metal assets per capita, kg

the new transformers, economy is limited only to a change in the specific consumption of electric power, and from their standpoint the increased price of the new transformer should not exceed this economy. At the same time, the increase in price for transformer steel does not cover the specific captial investments and running expenses involved in the production of transformer steel of improved quality. For ferrous metallurgy an improvement in the quality of this steel is wasteful and reduces the profit of metallurgical enterprises.

There are many such conflicts, and they likewise interfere with improvement of efficiency in ferrous metallurgy.

[154-6610]

6610
CSO: 1842

UDC 621.789:629.73.03-226.2

ON THE EFFECT OF ULTRASONIC TREATMENT ON THE FATIGUE STRENGTH OF BLADES IN A GAS TURBINE ENGINE

Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 80 pp 34-36 manuscript received 9 Oct 79

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[Abstract] Experiments were performed in the Vibration Laboratory of the Institute to determine the effect of ultrasonic surface strain hardening on the fatigue strength of compressor blades in a gas turbine engine and to establish the advantages of this over other treatments. Blades were tested in an apparatus featuring special stress concentrators with tuning to a natural frequency and transmission of energy through a set of balls by impact, the acoustic feedback connected to only one magnetostrictive transducer, in either a vertical or a horizontal configuration. The ranges of surface strain optimum with respect to fatigue strength were determined in a 3-level factorial experiment. The results indicate that blades made of the EI598 alloy steel and tested at 500° C under a 1300 Hz load acquire their highest fatigue strength when the stabilizing temper by thermomechanical treatment has followed contactive vibration and ultrasonic treatment after the serial manufacturing process, while blades made of the VT3-1 titanium alloy and tested at 300° C under a 340 Hz load acquire their highest fatigue strength when the stabilizing temper has followed the serial manufacturing process directly. In the latter case ultrasonic treatment was found to lower the fatigue strength by 6%, on the basis of 10^8 cycles. Figures 4; references 4: all Russian. [171-2415]

UDC 669.24:669.3:539.376

STRUCTURAL APPROACH TO DESCRIPTION OF HIGH-TEMPERATURE STEADY CREEP IN METALLIC MATERIALS

Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 80 pp 10-18 manuscript received 12 Oct 79

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[Abstract] An experimental study was made to verify two empirical relations describing steady-state creep in metallic materials at high temperatures, namely the exponential-law relation between strain rate and stress at high stresses and the power-law relation between strain rate and stress

at low stresses. These relations, based on a structural model of dislocations, also involve an exponential dependence on the temperature and on the activation energy of plastic deformation or of recovery, respectively. Flat specimens of 1) 99.68% pure M-2 technical and 99.97% pure electronically remelted copper, 2) 99.54% pure NP-2 technical and 99.99% pure electronically remelted nickel, 3) 80% Ni + 20% Cr and 66% Ni + 20% Cr + 14% Mo alloys, and 4) dispersion-hardened nickel with 1% vol. ZrO_2 were tested over the temperature ranges 1) 200-600° C, 2) 550-1000° C, 3) 750-1100° C, and 4) 700-1000° C respectively, both short thin specimens (10 x 3 x 1 mm) and long thick specimens (40 x 3 x 3 mm). Generally a destabilization with a coarsening of the dislocation substructure was found to occur in each material above some temperature, the Ni + 1% vol. ZrO_2 alloy remaining most stable of all within the 900-1000° C range. It is possible to determine the average characteristics of dislocation creep from a limited amount of test data and to select a material for maximum creep resistance at a given operating temperature. Figures 7; references 32: 17 Russian, 15 Western.
[171-2415]

UDC 539.374

HEAT-STRESSED STATE AND DURABILITY OF SURFACE LAYERS OF ELEMENTS OF STRUCTURES UNDER NON-STEADY-STATE THERMAL EFFECTS

Kiev PROBLEMY PROCHNOSTI in Russian No 2, 1980 pp 12-17 manuscript received 15 Feb 79

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[Abstract] High surface thermal stresses are caused when elements of structures are subjected to abruptly unstable thermal effects, and in the case of cyclic thermal changes these stresses can result in the cracking of surface layers even in the case of fairly plastic materials. An example is given of the employment of an approximate calculation diagram of a plate with a flow of heat normal to its surface for the purpose of calculating stresses and strains in areas of surface layers of parts with a covering. The assumption is made that the transfer of heat under non-steady-state conditions takes place only along the line normal to the plate's surface. A diagram of the plate is given, and the components of the stress and strain tensors are listed. Strains are distributed linearly along the z-axis. The problem of the stressed-strained state of the plate is solved in increments for the purpose of employing the theory of plastic flow. Increments in strains are represented as the sum of elasticity, plasticity, creep and thermal expansion components. Equations are derived for determining stresses and strains in the surface layers and for estimating the durability of surface layers. The basic rasson for cracking

of the surface layers is repeated thermomechanical loading. The key factor here is the number of cycles to failure in multiple repetition of the deformation scale characteristic of a specific cycle. This factor is determined by means of a modification of Manson's equation (1967). Curves are shown, illustrating the dependence of the number of cycles to failure on the magnitude of the deformation scale according to Manson's equation. A calculation example is given for determining thermal stresses in the wall of a cooled gas turbine vane made of ZhS6K alloy, which is represented diagrammatically as a plate with a plane slit. The thickness of the wall is 1.5 mm and at work in the surface layers of the vane are initial permanent compressive stresses measuring 36 kg/mm^2. In each loading cycle consisting of startup, operation and stopping, the vane is subjected to the thermal influence of a gas stream and the cooling air and is loaded with centrifugal tensile stresses of magnitude 10 kg/mm^2. The heat transfer coefficients on the inside and outside surfaces of the vane are 5000 kcal/m^2·h·deg and 3000 kcal/m^2·h·deg. Plastic deformation of the vane's surface layer takes place during initial loading. This deformation is 0.18 percent and takes place in an area 120 μ deep. In subsequent loading cycles the vane is deformed in the elastic region and this deformation is accompanied by the accumulation of creep, resulting in a gradual alteration of the diagrams of working and permanent stresses in the wall of the vane. Total relaxation of the initial permanent stresses occurs after 250 cycles. Then permanent tensile stresses appear at points on the vane's outside surface. The accumulation of creep resulting from nonuniform heating of the vane's wall practically ceases after 2000 hours. The working stresses are then uniformly distributed over the wall's thickness and equal the centrifugal tensile stresses. This is because the thermal stresses are totally compensated by stresses caused by accumulated creep. Stabilization of the cycle of changes in surface stresses takes place after 2000 cycles, or 2000 hours. The number of cycles to the appearance of cracking in surface layers is calculated as 2240 cycles. Figures 6; references 6: 5 Russian, 1 Western.
[107-8831]

UDC 535.338.4

ELECTRON STRUCTURE AND X-RAY SPECTRA OF NiTi

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 252, No 1, 1980 pp 87-89
manuscript received 25 Dec 79

BOLETSKAYA, T. K., YEGORUSHKIN, V. Ye., SAVITSKIY, Ye. M. and FADIN, V. P., Siberian Physico-Technical Institute imeni V. D. Kuznetsov, Tomsk State University

[Abstract] The intermetallic compound NiTi displays not only a "shape memory" but various other unique properties associated with the martensitic transformations occurring in that compound. In this connection,

the electron structure of NiTi was investigated and, on this basis, the x-ray spectra of this compound are discussed. The density of electron states in NiTi was determined by the tetrahedron method. The density of states N(E) was then compared with data on x-ray spectra by utilizing the $K\beta_5$-, $M_{2,3}$-spectra of nickel in the alloy and the x-ray electron spectrum, which reflect the structure of the valent band. It was found that the computed and experimental findings are in good agreement, that the computed electron structure fits satisfactorily the x-ray spectra; the fine structure of the spectrum was in good agreement with the computed N(E). The observed changes in the structure of $K\beta_5$ and $M_{2,3}$ bands with transition from metal to alloy are chiefly attributable to the changes in lattice symmetry accompanying that transition. Figures 1; references 13: 3 Russian, 10 Western.
[155-1386]

UDC 620.18:539.376:669.293.5

EFFECT OF STRUCTURE ON THE HIGH-TEMPERATURE STRENGTH OF A NIOBIUM ALLOY

Moscow METALLOVEDENIYE I TERMICHESKAYA OBRABOTKA METALLOV in Russian
No 5, 1980 pp 36-38

VASIL'YEVA, Ye. V. and TREKINA, M. I., Zil Higher Technical Training Plant

[Abstract] The effect of the structural state of a multicomponent niobium alloy (the NM20TETs alloy, containing 20.1% Mo, 2.7% Ti, 1% Zr, 0.05% C, 0.04% O, 0.05% N, and 0.006% H) on its high-temperature strength was investigated. Specimens of the alloy were subjected to a series of isochronous (1 hr) vacuum annealings (at a residual pressure of 10 mm Hg) at 1100-1800° C. This was followed by creep tests and by an investigation of the effect of grain size and structure on the steady-state creep rate. Microstructural tests showed that the extent of recrystallization of the specimens increases with an increase in their annealing temperature from 1,100 to 1,800° C, i.e., cumulative recrystallization, accompanied by an increase in grain size, increases with an increase in annealing temperature. This process reaches its peak at ~1500° C annealing temperatures, at which new boundaries (subboundaries) begin to form; the influx of dislocations to these boundaries increases the angle of disorientation between subgrains. Correspondingly, creep rates decrease for specimens annealed at 100-1500° C and increase for specimens annealed at 1500-1800° C. To maximize the high-temperature strength of NM20TETs alloy, grain size should be sufficiently large (up to 120 μm) but not so large as to induce the processes of the coarsening of substructure. Figures 3; references 7: 6 Russian, 1 Western.
[152-1386]

UDC 666.762.85:66.094.3:620.186

HIGH-TEMPERATURE OXIDATION OF COMPLEX CARBIDES OF NIOBIUM AND ZIRCONIUM AT LOW OXYGEN PRESSURES

Ordzhonikidze IVUZ, TSVETNAYA METALLURGIYA in Russian No 2, 1980 pp 81-85
manuscript received 20 Feb 79

AFONIN, Yu. D., SHALAGINOV, V. N., BEKETOV, A. R. and ALYAMOVSKIY, S. I.,
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[Abstract] The results are given of a thermogravimetric analysis of the oxidation of complex carbides of niobium and zirconium in a stream of purified oxygen under pressures of 0.2 to 50 mm Hg over the temperature range of 600 to 1600° C. Specimens were prepared from carefully blended powders of $NbC_{0.94}$ and $ZrC_{0.92}$ with fineness of 0.5 to 4 microns, by sintering in a resistance furnace in argon. The maximum sintering temperature varied from 2900 to 3300° C. Specimens were held at the maximum temperature for 10 min and were then subjected to homogenizing annealing at 2600° C for 2 hours. An x-ray phase analysis showed that the specimens produced were homogeneous and were solid solutions with a structure of the NaCl type. The following alloys were produced: $NbC_{0.94}$, $Nb_{0.95}Zr_{0.05}C_{0.94}$, $Nb_{0.90}Zr_{0.10}C_{0.96}$, $Nb_{0.80}Zr_{0.20}C_{0.90}$, $Nb_{0.50}Zr_{0.50}C_{0.96}$, $Nb_{0.35}Zr_{0.65}C_{0.93}$, $Nb_{0.25}Zr_{0.75}C_{0.94}$ and $ZrC_{0.92}$. Curves are shown, illustrating the dependence of the degree of oxidation of a complex monocarbide on composition, temperature and oxygen pressure. The curves show a characteristic minimum corresponding to an equimolar composition and maximum corresponding to a carbide containing 75 molar percent $ZrC_{0.92}$. The value of the maximum depends on the temperature and the oxygen pressure. With lowering of the pressure the maximum shifts toward the region of higher temperatures. Also, the higher the oxygen pressure, the lower the minimum. It is demonstrated that specimens with an equimolar composition possess maximum resistance to oxidation. The results are given of a determination of the phase composition of the oxide films formed. For compositions with a zirconium carbide content of up to 50 molar percent, oxidation is determined by the rate of decomposition of oxide carbides and by diffusion of oxygen through the dense inner layer of scale. On the other hand, for compositions with a $ZrC_{0.92}$ content greater than 65 molar percent, oxidation is determined by the rate of crystal chemical transformation. An electron diffraction analysis revealed that for compositions with a zirconium carbide content of up to 50 molar percent, the formation of an oxide film consisting of a solid solution of ZrO_2 and NbO_2 with a structure of the rutile type takes place at the first stages of oxidation. With further oxidation, two-layered scale forms, whose inner dense layer consists of NbO_2 or a solid solution of ZrO_2 in NbO_2 and whose outside friable layer consists of Nb_2O_5 or the mixture $Nb_2O_5 + Nb_2O_5 \cdot 6ZrO_2$. Here the rate of oxidation is determined chiefly by the rate of disintegration of oxycarbides. For compositions with a zirconium carbide content greater

than 65 molar percent, the formation of the chemical compound $Nb_2O_5 \cdot 6ZrO_2$ and of single-layered scale is preferred. Then oxidation takes place chiefly according to an intercrystallite mechanism. Figures 3; references 8: 7 Russian, 1 Western.
[162-8831]

UDC 669.71:539.23

CONCERNING THE SHIFT IN THE EUTECTIC POINT WHEN ANNEALING VACUUM FILMS OF ALUMINUM ON MONOCRYSTALLINE SILICON SUBSTRATES

Moscow FIZIKA I KHIMIYA OBRABOTKA MATERIALOV in Russian No 3, 1980 pp 73-76 manuscript received 18 Aug 78

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[Abstract] From the viewpoint of thermodynamics, a calculation was made of the snift in the eutectic point in relation to temperature and concentration as a function of the particle size level of films of aluminum sprayed onto monocrystalline silicon substrates. In addition, the lowering of the eutectic temperature when specimens are annealed was confirmed experimentally. An analysis of thermodynamic potentials of interaction of the components demonstrated that whereas for silicon the thermodynamic potential of a macroscopic system must be used, for aluminum it is necessary to take into account the particle size of the system, which is expressed in a first approximation in terms of the heat of formation. The excess energy of the aluminum film results in a shift in the eutectic point on the Al-Si state diagram. The shift in the eutectic point in relation to temperature, T_e, and concentration, y_e, was estimated in an approximation of regular solutions, taking into account the relative stability of various phases, in that each region on the temperature-composition phase diagram corresponds to the phase whose free energy is less than that of other competing phases. Calculations were performed on a BESM-4M computer. An Al-Si state diagram is given, which demonstrated that if the aluminum is in the metastable state a shift is observed in the eutectic point, both in relation to temperature and concentration. Calculated values of T_e and y_e as a function of the particle size of the aluminum for the Al-Si system show a reduction in T_e and y_e with an increase in the particle size of aluminum films. For obtaining an experimental confirmation of this lowering of T_e, thin films of aluminum, without heating the substrate, were sprayed by means of thermal volatilization in a 10^{-6} torr vacuum onto the (111) surface of specimens of monocrystalline grade KDB-14 silicon 250 microns thick. For the purpose of cleaning the condensing surface of contaminants, the silicon specimens, directly before spraying, were treated in a glow-discharge. After spraying, the specimen was attached to the heater and the topography of the surface

of the film was photographed prior to annealing, by means of an EF-4 scanning electron microscope. Then a specimen was heated rapidly to 550° C, held for 15 min and photographed. Then the temperature was raised to 600° C, the specimen was again annealed for 15 min and the topography of the film's surface was again photographed. In the annealing process the specimen's temperature was controlled by means of a Chromel-Alumel thermocouple. A photograph taken before annealing shows that the surface of the aluminum film 200 Å thick is even and is transparent for an electron beam; through the film, on the surface of the silicon, are quite obvious individual fine scratches, representing traces of grinding and polishing. With oblique incidence of the electron beam, in individual places on the surface of the aluminum film shadows are observed from sharp conical protuberances which are preserved in the process of subsequent annealing and serve as reference points; the height of these protuberances is considerably greater than the thickness of the film. These protuberances were formed when the surface of the silicon was cleaned in the glow-discharge. With annealing of the specimen at 600° C the eutectic phase is observed almost over the entire surface. Over a considerable area of the film a eutectic formed also at an annealing temperature of 550° C, which is 27° C below T_e for the Al-Si system according to the state diagram. The highly dispersed state of aluminum films after they are sprayed onto a cold silicon substrate results in the lowering of T_e in annealing. Figures 3; references 8: all Russian.
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Sept. 25, 1980